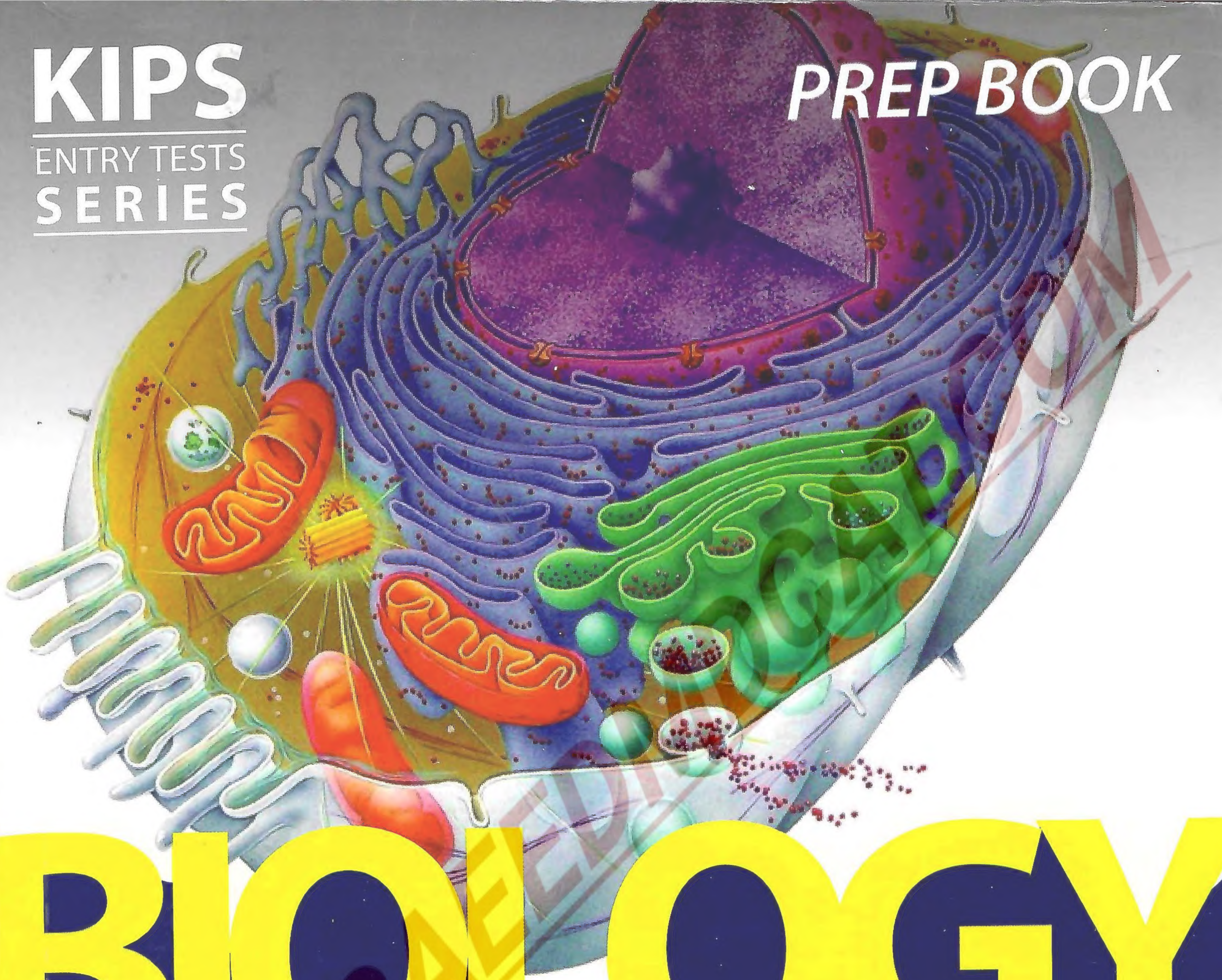
KIPS

ENTRY TESTS SERIES

PREP BOOK



BIOLOGY

NATIONAL MDCAT

- Topic-wise Complete Syllabus
- Comprehensive Course Revision
- Detailed Explanation of Topics
- Key Points, Tables, Flow Sheets & Diagrams
- Easy to Remember; Points to Ponder

A Kitab Dost Publication

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TOPIC-1 » CELL STRUCTURE AND FUNCTION

COURSE CONTENT

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- Plasma Membrane
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- Cytoplasmic Organelles; Ribosomes, Endoplasmic Reticulum, Golgi Apparatus, Lysosomes, Peroxisomes and Glyoxysomes, Vacuoles, Mitochondria, Plastids, Nucleus
- Comparison Between Prokaryotic and Eukaryotic cells

STRUCTURE OF A GENERALIZED CELL

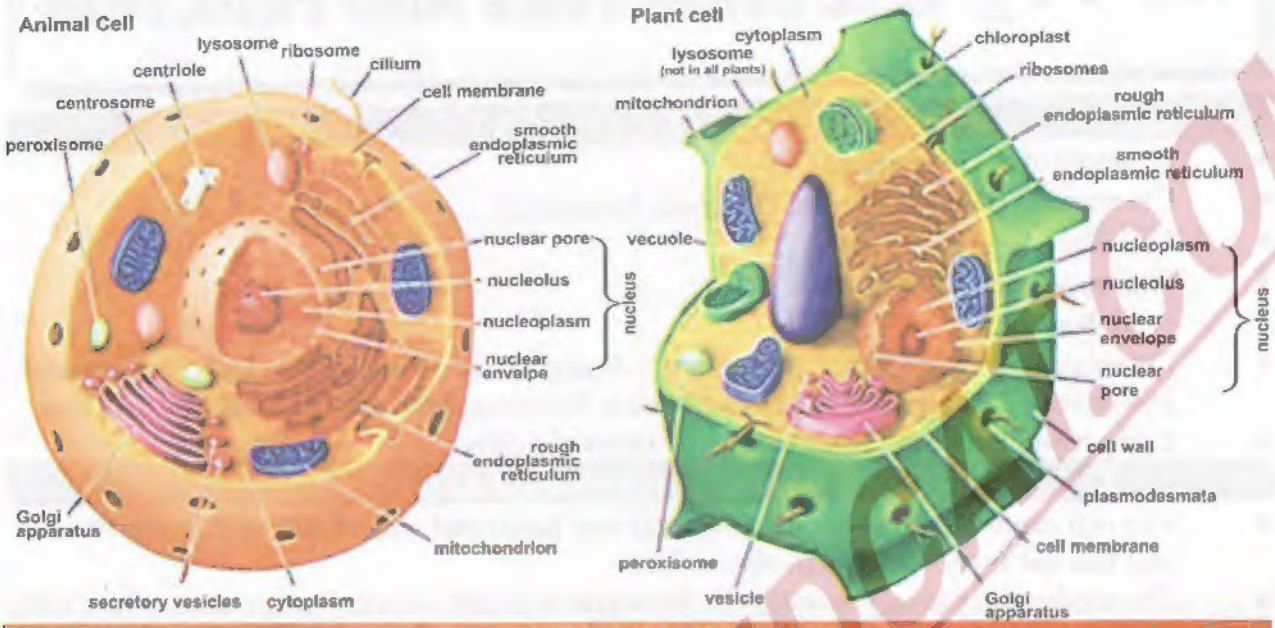
- The cell can be defined as 'the structural and functional unit of life' and is the smallest unit that can carry out all activities of life.
- The modern technology enables the Biologist to isolate various components of the cells including its organelles by a process of **cell fractionation**.
- During cell fractionation, the tissues are homogenized or disrupted with special instruments and various parts of the cells are separated by density gradient centrifugation.
- The various cellular parts separate out in different layers depending upon their size, weight, and density of the medium.
- A cell consists of the following basic components:

(i) Plasma membrane, also cell wall in plant cells
(ii) Cytoplasm, containing cells organelles
(iii) Nucleus, with nuclear or chromatin material

COMPARISON BETWEEN TYPICAL PLANT AND ANIMAL CELL

In the traditional system of classification, all organisms are divided into plants and animals. The main comparative features between animal and plant cells are listed in the following table.

Features	Animal Cell	Plant Cell
Cell wall	×	✓
Plastids	×	✓
Glyoxysomes	×	✓
Centrosome (Centrioles)	✓	×
Mitotic Apparatus	Spindles + Asters	Spindles Only
Cytokinesis	Inwards	Outwards
Lysosomes	✓	×
Flagella	✓	×
Phagocytosis	✓	×
Nucleus	Central	Peripheral
Vacuoles	Small and many	Large and single
Storage Products	Glycogen	Starch



CELL WALL

Introduction to Cell Wall

- It is the outermost boundary in plant cells and absent in animal cells.
- The cell wall of plant cell is different from that of prokaryotes, both in structure and chemical composition.
- It is **secreted by protoplasm** of the cell.
- Its thickness varies in different cells of the plant.
- Prokaryotic cell wall lacks cellulose; its strengthening material is peptidoglycan or murein while fungal cell wall contains chitin.

Structure

Cell wall is composed of three main layers which are:

- Primary wall
- Middle lamella
- Secondary wall

(i) Primary Wall

The primary wall is a true wall and develops in newly growing cells. The primary wall is composed of:

- **Cellulose** whose molecules are arranged in a crisscross arrangement.
- Some amount of **pectin and hemicellulose is** also deposited in it.

(ii) Middle Lamella

The middle lamella is first to be formed in between the primary walls of the neighboring cells.

(iii) Secondary Wall

The secondary wall is formed on inner surface of primary wall. It is comparatively thick and rigid as compared to primary wall.

Chemically, it is composed of **inorganic salts, silica, waxes, lignin,** and **cutin** etc.

Functions of Cell Wall

Cell wall is very important. It performs following important functions:

(i) It provides a **definite shape** to the cell

(ii) It makes cell **rigid**

(iii) It provides **protection** to inner parts of cell.

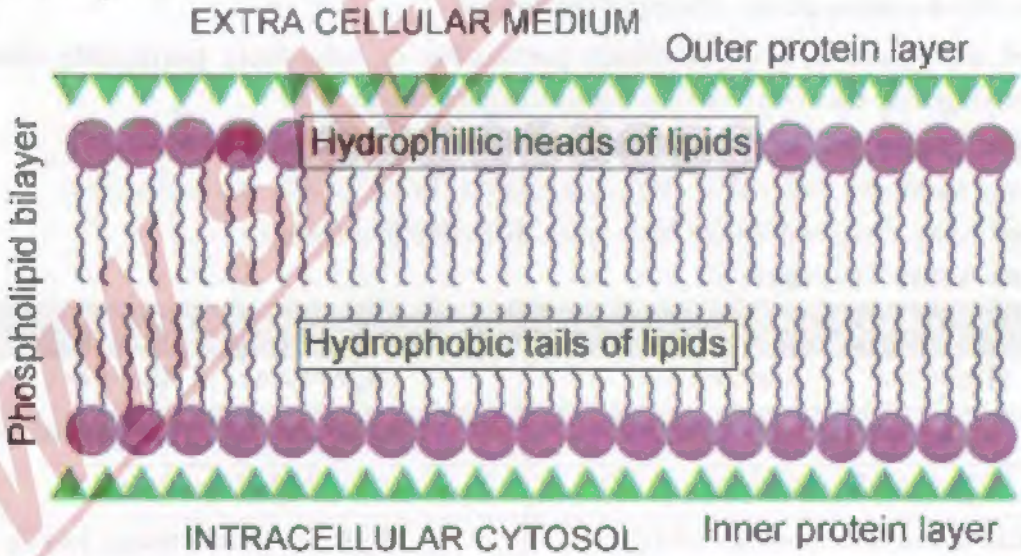
(iv) It **does not act as a barrier** to the materials passing through it.

PLASMA MEMBRANE

- Cell membrane is the outer most boundary of the animal cell while covered by cell wall in a plant cell.
- Plasma membrane is about 7 nm thick.
- Chemically composed of:
  - Proteins (60- 80 %)
  - Lipids (20- 40 %)
  - Small amount of carbohydrates is also present in the form of glycolipids and glycoproteins.

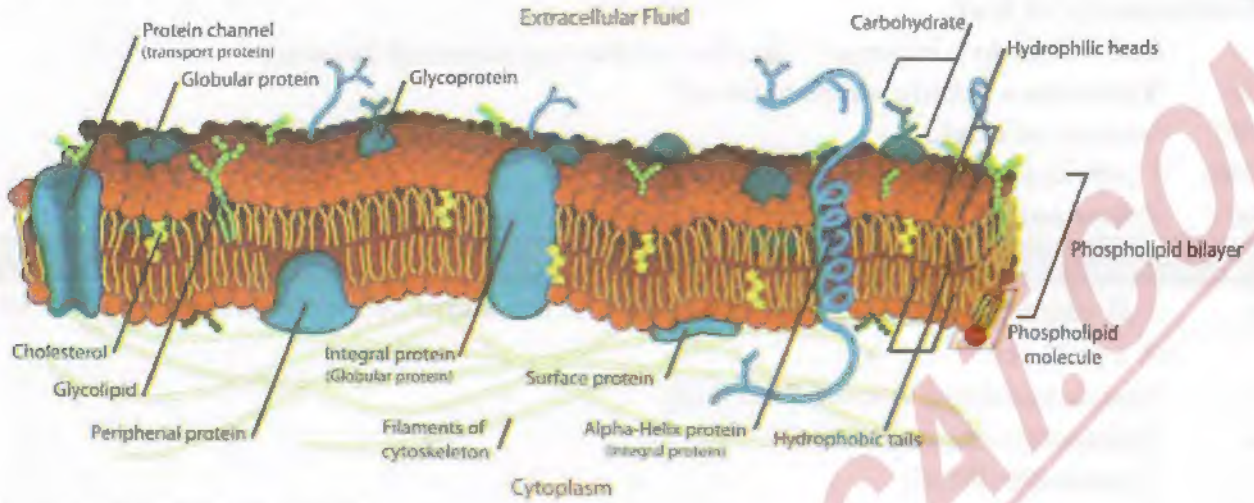
Unit Membrane Model

- This model was presented by J. David Robertson in 1959.
- According to Unit Membrane model, the cell membrane is composed of lipid bilayer sandwiched between inner and outer layer of proteins.
- This structure has hydrophobic component i.e. central non-polar part of phospholipid molecules and a hydrophilic part i.e., outer polar component of phospholipids and globular proteins covering both sides.



Fluid Mosaic Model

- This model was proposed by S.J. Singer and G.L. Nicolson in 1972.
- According to fluid mosaic model, protein layers are not continuous and are not confined to the surface of the membrane but are embedded in lipid layers in a mosaic manner. These protein molecules may function as a gateway (charged pore) for the transport of materials.
- This model at present is the **most accepted one**.



Role of Different Molecules

- **Phospholipids** form lipid bilayer.
- **Cholesterol** helps to stabilize this lipid bilayer.
- **Channel proteins** allow a particular molecule or ion to cross the plasma membrane freely.
- **Carrier proteins** selectively interact with a specific molecule or ion so that it can cross the plasma membrane.
- **Glycoproteins** and **glycolipids** are found on cell surface and help in recognition.

Transport Mechanisms across Plasma Membrane

- Cell membrane is a **differentially permeable** or **selectively permeable membrane**, allowing only the selective substances to pass through it.
- **Lipid soluble** substances pass through cell membrane more easily than others.
- Many **small** gas molecules, water, glucose etc. being neutral can easily cross.
- **Ions** being charged particles have some difficulty in crossing.

Passive and Active Transport

Passive Transport	Active Transport
High Conc. → Low Conc.	Low Conc. → High Conc.
Along the concentration gradient	Against the concentration gradient
Downhill movement	Uphill movement
Without use of cell energy (ATP)	With use of cell energy (ATP)

Diffusion and Osmosis

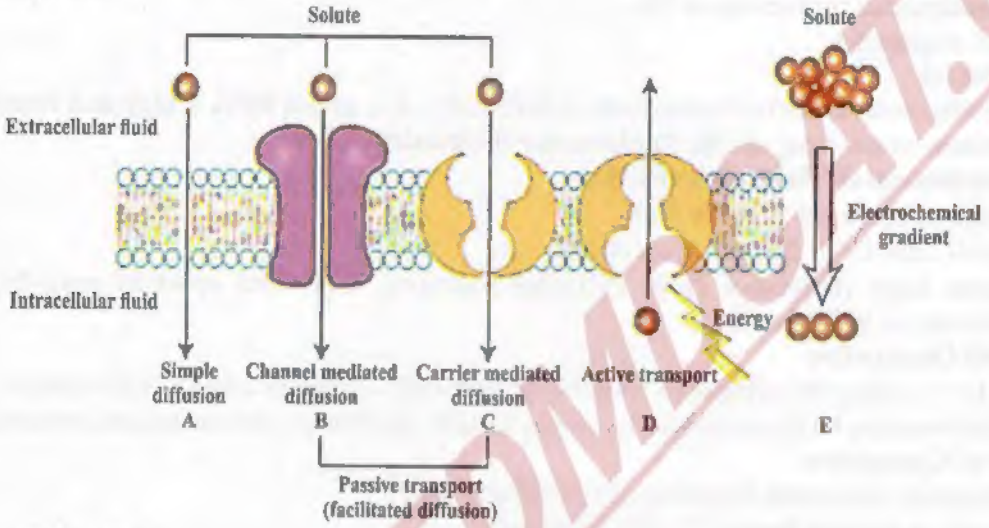
- Movement of solute molecules from higher concentration to lower concentration is called diffusion e.g. movement of respiratory gases.
- Movement of water molecules across the membrane from higher water potential to lower water potential is called osmosis.

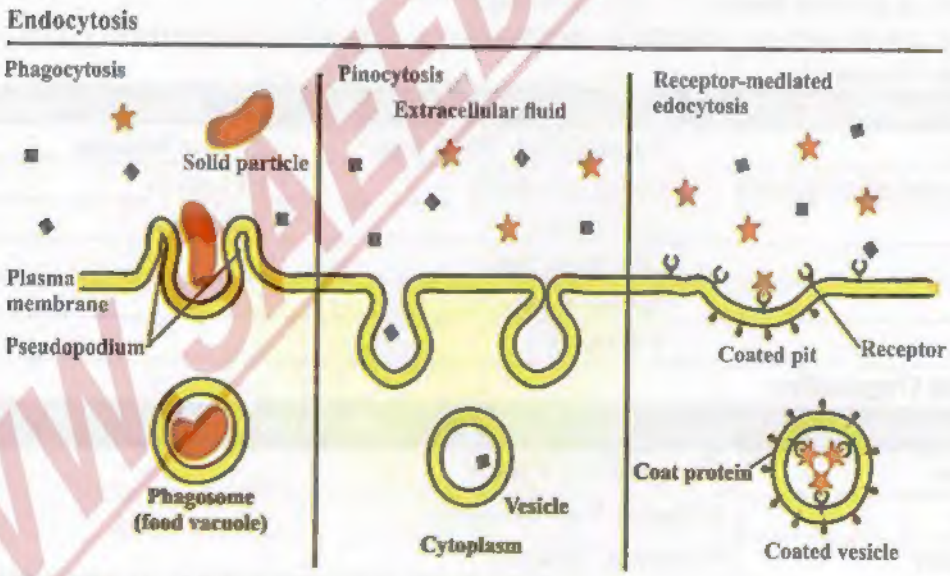
Facilitated Diffusion

- It is a type of carrier mediated transport in which molecules move from higher concentration to lower concentration with the help of carrier proteins.

Endocytosis and Exocytosis

- Intake of materials along the infoldings of cell membrane in the form of vacuole is called endocytosis.
- Intake of material in solid form is called **phagocytosis** while intake in fluid form is called **pinocytosis**.





Some Other Functions of Plasma Membrane

Plasma membrane regulates cell's interaction with its environment by controlling transport of materials across the cell. Transport across plasma membrane occur to;

(i) Obtain nutrients
(ii) Excrete waste substances
(iii) Secrete useful substances
(iv) Generate ionic gradients essential for nervous and muscular activities
(v) Maintain a suitable pH within the cells for enzyme activity

CYTOPLASM

- The living contents of the eukaryotic cell are divided into nucleus and the cytoplasm, the two collectively form **protoplast**.
- Cytoplasm consists of an aqueous ground substance containing a variety of cell organelle and other inclusions such as insoluble waste and storage products.

Composition

Cytoplasm contains:

(i) Cytosol
(ii) Fundamental molecules of life
(iii) Cell organelles

(i) Cytosol

It is the soluble part of cytoplasm. Chemically, it is about **90% water** and forms a solution containing all the fundamental molecules of life.

(ii) Fundamental Molecules of Life

- Some of them are in ionic form.
- Small molecules form true solutions.
- Some large molecules form colloidal solutions. Colloidal solution may be sol (non-viscous) or gel (viscous).

(iii) Cell Organelles

In living cells, the cytoplasm contains several cell organelles such as endoplasmic reticulum, mitochondria, Golgi complex, nucleus, plastids, ribosomes, lysosomes and centrioles.

Function of Cytoplasm

The most important functions of cytoplasm are:

(i) It acts as a **store house** of vital chemicals.
(ii) It is a **site of certain metabolic pathways** e.g. Glycolysis and protein synthesis

Cytoplasmic Organelles

Non-Membranous	Single Membranous	Double Membranous
Ribosomes	Endoplasmic Reticulum	Mitochondria
Centrioles and Microtubule	Golgi apparatus	Plastids
	Lysosomes	Nucleus
	Glyoxysomes	
	Peroxisomes	
	Vacuoles	

Discovery of Organelles

Organelles	Discovered By
Ribosomes	George Emil Palade
Centrioles	Edouard Van Beneden
Cytoskeleton	Nikolai K. Koltsov
Endoplasmic Reticulum	Keith R. Porter, Albert Claude, Brody Meskers and Ernest F. Fullam
Golgi apparatus	Camillo Golgi
Lysosomes	C. R. De Duve
Peroxisomes	C. R. De Duve
Glyoxysomes	Harry Beevers
Mitochondria	Richard Altmann
Nucleus	Robert Brown

RIBOSOMES

Cell contains many tiny granular structures known as ribosomes.

Chemical Composition

- Ribosomes are **ribonucleo- proteins** particles.
- Ribosomes consist of **RNA** and **proteins** in almost equal proportion.

Assembly of Ribosomes

- Ribosomes are assembled in the **nucleolus**.
- From nucleolus they are transported to the cytoplasm through nuclear pores.

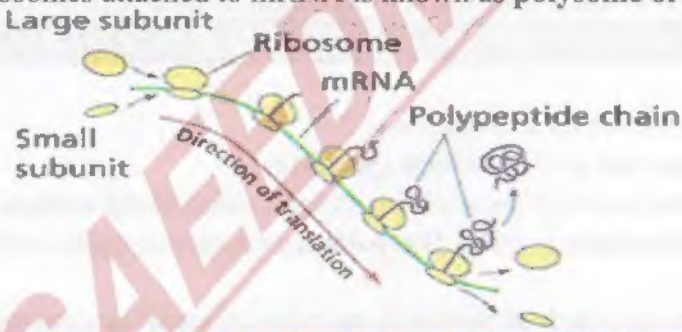
Form and Physical Structure

- They exist in two forms, either dispersed in the cytoplasm or attached with rough endoplasmic reticulum (RER) as tiny granules.
- Ribosomes consist of **two subunits**: larger subunit and smaller subunit.
- Attachment of both subunits is controlled by **Mg^{2+} ions**.
- Ribosomes are attached to 5' end of mRNA through smaller subunits.

	Ribosome	Larger Subunit	Smaller Subunit
Prokaryotic Ribosomes	Small, 70S	50S	30S
Eukaryotic Ribosomes	Large, 80S	60S	40S

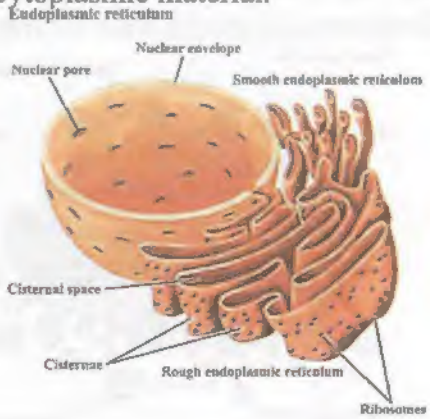
Functions

- Ribosomes are the factory for **protein synthesis**.
- A group of ribosomes attached to mRNA is known as **polysome or polyribosome**.



ENDOPLASMIC RETICULUM

- Network of interconnected channels extending and often continues with cell membrane to the nuclear membrane is called endoplasmic reticulum.
- They vary in appearance from cell to cell.
- **Cisternae** are spherical or tubular membranes which separate the material present in these channels from that of cytoplasmic material.



Types and Functions

There are two **morphological forms** of endoplasmic reticulum; RER and SER.

(i) **Rough E.R**

- RER has ribosomes attached to its external cisternal surface.
- Contain **cisternae sacs**.
- These are directly connected with outer nuclear membrane.
- RER is involved in the **synthesis of proteins**.
- After synthesis, they are either stored in the cytoplasm or transported out of the cell through these channels.

(ii) **Smooth E.R**

- These are the one which are without ribosomes.
- Contain **cisternae in the form of tubules**.
- SER helps in **metabolism** of various types of molecules particularly lipids.
- SER is involved in the **detoxification** harmful drugs.
- SER is also responsible for the **transmission of impulses** e.g. in muscles cells and nerve cells.
- Formation of Golgi vesicles

General Functions of E.R

- They provide **mechanical support** to the cell, so that its shape is maintained
- They are also involved in **transport** of materials from one part of the cell to the other.

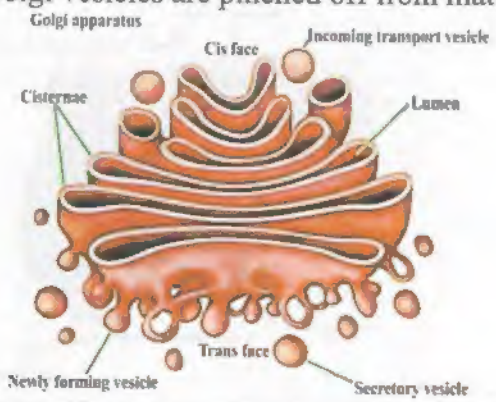
GOLGI APPARATUS

Introduction

- Single cisternal sac is called **Golgi body**.
- Stack of cisternae sacs is called **Golgi apparatus**.
- Stack of cisternae sacs with associated vesicles is called **Golgi complex**.
- Golgi apparatus in plants is called **Dictyosomes** which are used in construction of cell wall.

Structure

- Golgi apparatus is a stack of flattened, membrane bound sacs called cisternae.
- Golgi complex is a complex system of interconnected tubules around the central stacks. The cisternae together with associated vesicles are called Golgi complex.
- Golgi apparatus has two faces i.e. forming face and maturing face.
- **Forming face** is outer face also called as 'cis face'. Vesicles that bud off from smooth endoplasmic reticulum are fused together to form cisternae of Golgi apparatus at forming face.
- **Maturing face** is inner face also called as 'trans face'.
- Secretory granules/ Golgi vesicles are pinched off from maturing surface.

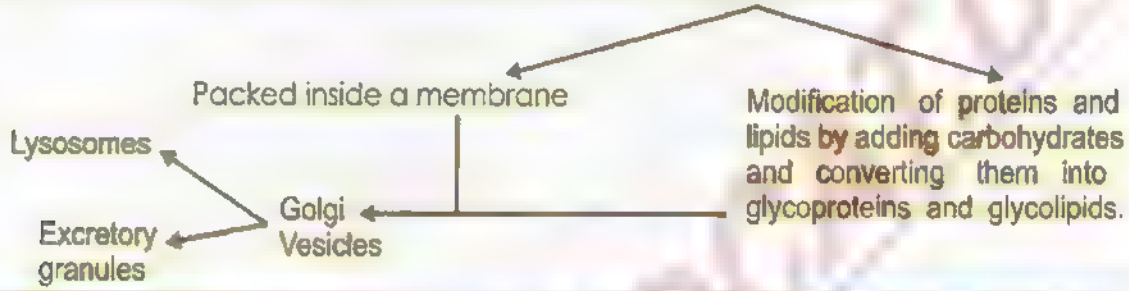


Functions

- They are concerned with the **cell secretion**.
- They are involved in **modification of molecules**. Most important modifications are addition of carbohydrates into proteins and lipids and **formation of glycoproteins** and **glycolipids.**
- During cytokinesis in plant cells, these are involved in formation of **phragmoplast.**

Pathway and Fate of Processed Vesicles

Ribosomes → Endoplasmic reticulum → Transport vesicles → Golgi apparatus



LYSOSOMES

Introduction

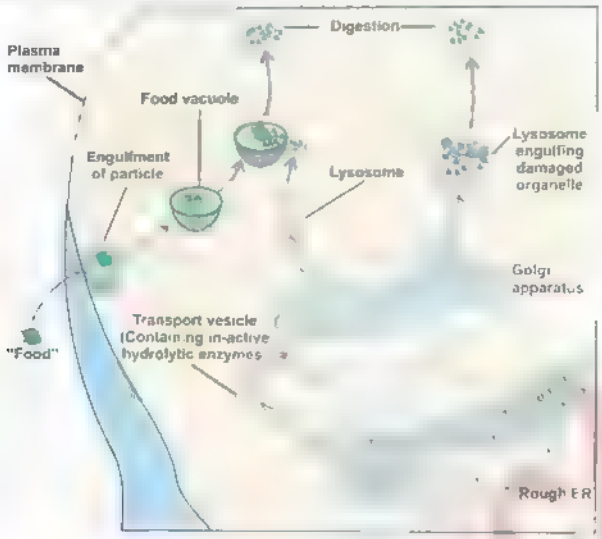
- Lysosomes (Lyso ~ Splitting: Soma = Body) are cytoplasmic organelles which are found in most eukaryotic cells and are different from others due to their morphology.
- These were isolated as a separate component for the first time by De Duve in 1949.

Structure

- Bound by a **single membrane** and are simple sacs (vesicles) rich in **acid phosphatase** and several other digestive or **hydrolytic enzymes.**
- These enzymes are synthesized on RER and are further processed in the Golgi apparatus. The processed enzymes are budded off as Golgi vesicles and are called **primary Lysosomes.**

Functions

- Any foreign object that gains entry into the cell is immediately engulfed by the lysosomes and is completely broken into simple digestible pieces. This process is known as **phagocytosis.**
- The ingested food of cell is stored in vesicles, called food vacuoles. Once a lysosome has fused with food vacuole, the resulting structure is called secondary lysosome. Digested products are absorbed by cytoplasm while remaining wastes containing vesicle is now called contractile vacuole. This is called **intracellular digestion.**
- They are also involved in the **autophagy**. During this process some old, worn out parts of cells, such as mitochondria are digested. Such lysosomes are called autophagosome. Such process also occurs during starvation.
- Their enzymes can also result in **degeneration of cell**, as may occur during some developmental processes. This type of cell death is called autolysis. Removal of tadpole tail during metamorphosis is an example of lysosomal activity.
- Lysosomes also release enzymes for **extra cellular digestion**.



Storage Diseases

- Several congenital diseases have been found to be due to accumulation within the cell of substances such as glycogen or glycolipids. These are called storage diseases. 20 such diseases have been discovered so far.
- These diseases are produced by a mutation that affects one of the lysosomal enzymes involved in the catabolism.
- In **glycogenosis type II disease**, the liver and muscle appear to be filled with glycogen within membrane bound organelles. In this disease, an enzyme that degrades glycogen to glucose is absent.
- **Tay-Sach's disease** is because of absence of an enzyme that is involved in the catabolism of lipids. Accumulation of lipids in brain cells leads to mental retardation and even death.

PEROXISOMES AND GLYOXYSOMES

Peroxisomes

- De Duve and co-workers isolated in 1965 particles from liver cells. In animals, they are most common in liver and kidney cells.
- They have also been found in protozoa, yeast and many cell types of higher plants.
- The name peroxisome was applied because this organelle is specifically involved in the formation and decomposition of H_2O_2 in the cell.

Structure

- These are single membrane enclosed cytoplasmic organelles found both in animal and plant cells.
- They originate from endoplasmic reticulum.
- They are approximately 0.5μm in diameter.
- They are rich in oxidative enzymes, such as peroxidase, catalase, glycolic acid oxidase and some other enzymes.
- Catalases are involved in breakdown of hydrogen peroxide into water and oxygen.

Functions

- They are involved in formation and decomposition of hydrogen peroxide.

Glyoxysomes

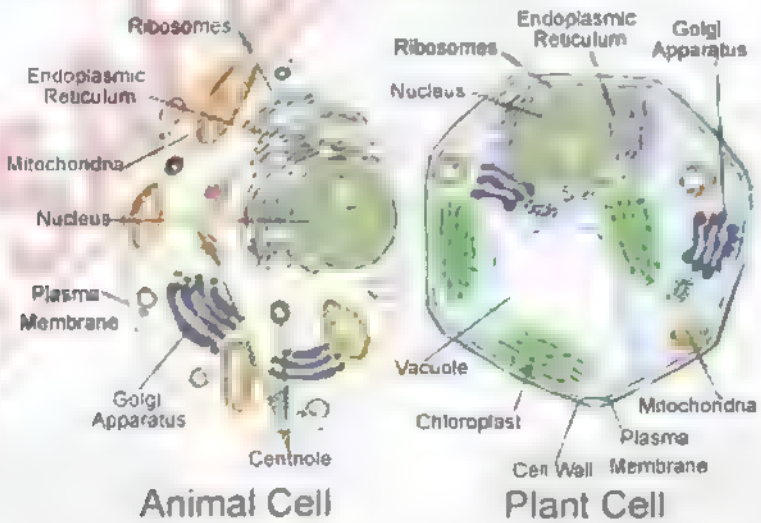
- Plants contain an organelle, which in addition to glycolic acid oxidase and catalase, also possess a number of enzymes that are not found in animal cells. This Organelle is called Glyoxysomes.
- Glyoxysomes are present only during a short period in the germination of **the lipid-rich seed** and is absent in lipid-poor seed such as pea.

Function

- Glyoxysomes are the most abundant in plant seedlings, which rely upon stored fatty acids to provide them with the energy and the material to begin the formation of a new plant.
- One of the primary activities in these germinating seedlings is the conversion of stored fatty acids to carbohydrates, through **Glyoxylate cycle**, the enzymes of which are located in the Glyoxysomes.
- In seeds rich in lipids such as castor bean and soya-beans, Glyoxysomes are the sites for breakdown of fatty acids to succinate.

VACUOLES

- They are present both in plant and animal cell.
- In plant cell, a large central vacuole is present that is formed by coalescence of smaller vacuoles.
- In animal cell, small but numerous vacuoles are present.



Functions

- They serve to **expand** the plant cells without diluting their cytoplasm
- They act as a site for **storage** of water and cell products or metabolic intermediates.
- They maintain the cells' **turgor**, responsible for support, and rigidity of the leaves and young parts of the plants.

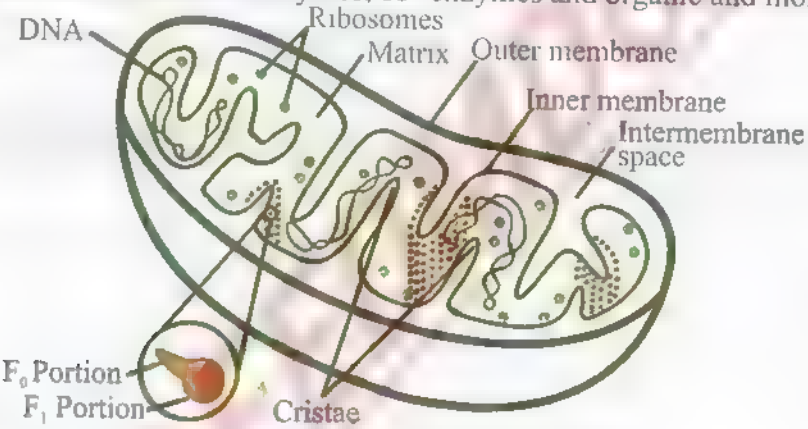
MITOCHONDRIA

Introduction

- They are also called **power house** of the cell.
- They are **self-replicating** organelles.

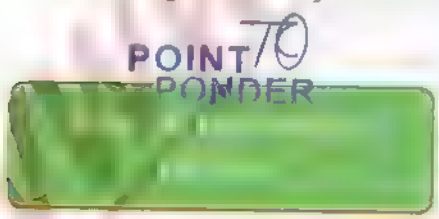
Structure

- Their **size and number** vary depending on the physiological activity of the cell.
- They also contain **DNA and ribosomes**; thus, some proteins may also be synthesized in them.
- When seen under compound microscope they appear as vesicles, rods, filaments.
- When seen under electron microscope, then it shows that they are bound by two membranes, a smooth outer membrane and an inner one forming infoldings **(cristae)** in mitochondrial matrix and they show complex morphology.
- The inner surface of cristae in the mitochondrial matrix contains small knob like structure called **F1/elementary particles.**
- **Mitochondrial matrix** contains enzymes, co- enzymes and organic and inorganic salts.



Functions

- They manufacture and supply **energy** to the cell.
- Enzymes in mitochondrial matrix help in metabolic processes like **Krebs cycle, aerobic respiration**, and **fatty acid metabolism**. These processes extract energy from the organic food and convert them into ATP, an energy rich compound, which provides energy to the cell on demand.
- ADP is regenerated by mitochondria into ATP.



PLASTIDS

- Membrane bounded, mostly pigment containing bodies present in the cells are called plastids.
- These are present in plant cells only.

Chloroplast

- Chloroplasts vary in their shape and size with a diameter of 4-6 μm.
- Under light microscope they are heterogeneous structures with small granules called grana embedded in the matrix.
- **Envelop** is double membrane covering.
- **Stroma** covers most of the volume of the chloroplast, contains proteins, some ribosomes and small circular DNA. Here CO_2 is fixed to manufacture sugar. Proteins are also synthesized here.
- **Thylakoids** are flattened vesicles which arrange themselves to form grana and inter-grana.
- **Grana** are piles of thylakoids stacked on each other like coins 50 or more thylakoids piled to form one granum. On these layers, chlorophyll molecules are arranged, thus appear green.
- **Inter-grana** are a non- green part which interconnects grana
- Membranes of grana are sites where sunlight energy is trapped and ATP is formed.
- Chloroplasts are self-replicating organelles.

Chromoplasts

- They impart colours to the plants other than green.
- They are present in the **petals of the flowers and in the ripened fruit**.
- They help in **pollination and dispersal of seeds.**

Leucoplasts

- They are **colorless**.
- They **are triangular, tubular** or of some other shape.
- They are found in the **underground parts** of the plants and **store food**.

NUCLEUS

Introduction

- It is the most prominent and most important part of the cell, also called as brain of cell.
- They are visible only in non- dividing cells.
- In animal cell they are **central** in position with exception of skeletal muscle fiber.
- In plant cells they are pushed to **periphery** due to the presence of large vacuole.
- They may be irregular or spherical in **shape**.
- A cell containing single nucleus is called **mononucleate**, two as **binucleate** and with more than two as **multinucleate**.

POINT TO PONDER

POINT TO PONDER

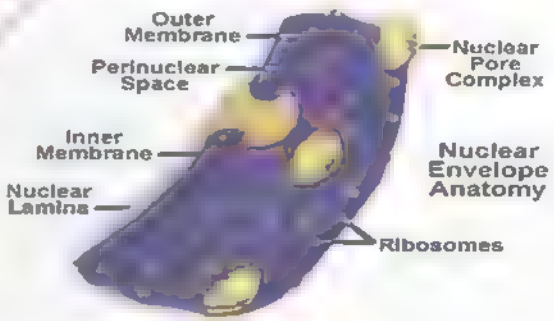
Can you give example of binucleated uninucleated & multinucleated cells in human body?

Structure

- Nucleus is composed of nuclear membrane, nucleoli, nucleoplasm and chromosomes or chromatin network.

A) Nuclear Membrane

- Nuclear membrane also called as nuclear envelope separates the nuclear material from the cytoplasm.
- It is a **double layered** structure. Outer layer continuous with the endoplasmic reticulum and the inner one encloses the nuclear contents.
- These membranes have same structure as per fluid mosaic model.



B) Nuclear Pores

- Nuclear pores result from the fusion of outer and inner membranes. They are composed of specialized transport proteins called **nucleoporins**.
- They act as a **gateway** for the exchange of materials with the cytoplasm.
- Their **number** is variable depending upon the differentiation of the cell i.e. undifferentiated cells like eggs have 30,000 pores / nucleus while erythrocytes, well differentiated cells have 3- 4 pores/nucleus.

C) Nucleoplasm

- It is transparent semi-fluid ground substance.
- It contains DNA, RNA, proteins, Mg^{+2} ions, free nucleotides and enzymes (DNA and RNA polymerase).

D) Nucleolus

- Nucleolus is non-membranous, darkly stained body within the nucleus.
- Nucleoli may be one or more.
- They appear during interphase & disappear during cell division.
- RNA (rRNA) is synthesized and stored in it.
- Nucleolus is composed of two regions: **peripheral granular area** containing precursors for ribosomal subunits and **central fibril area** containing rRNA and rDNA.

- It is the **factory for ribosome synthesis.**

POINT TO PONDER

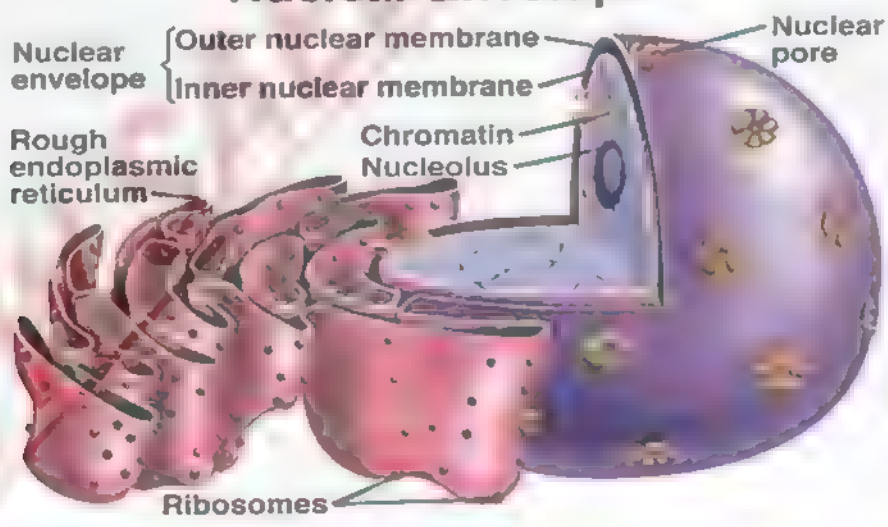
E) Chromatin & Chromosome

- Each chromosome is a thread like structure resulting from organization of chromatin material during cell division.
- Chemically chromosomes are composed of **DNA and protein.**
- Under compound microscope they appear to be made of arms (chromatids) and a centromere, the place where spindle fibers are attached during cell division.
- **Centromere** (primary constriction) is the place on the chromosome and **Kinetochore** is a place on centromere where spindle fibers are attached during cell division.

Chromosome Number In Different Species

Species	Diploid (2n)	Haploid (n)	Species	Diploid (2n)	Haploid (n)
Man	46	23	Frog	26	13
Chimpanzee	48	24	Drosophila	8	4
Onion	16	8	Potato	48	24
Garden Pea	14	7	Pigeon	80	40

Nuclear Envelope

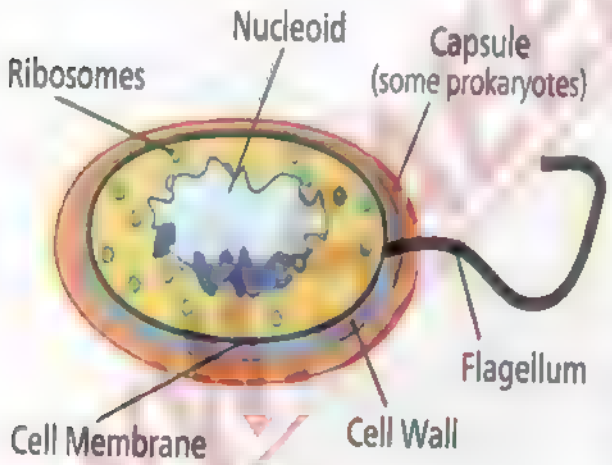


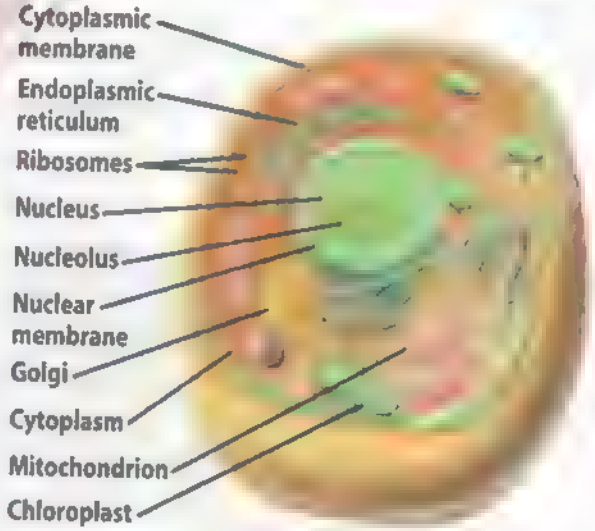
Functions

- It controls all the metabolic activities of cell.
- It has all the genetic information in a cell.

COMPARISON BETWEEN PROKARYOTIC AND EUKARYOTIC CELLS

Well Defined Nucleus	Absent	Present
DNA	Submerged in cytoplasm	Present in nucleus
Type of DNA	Circular DNA as nucleoid	Linear DNA in nucleus
Membrane Bounded Organelles	Absent	Present
Ribosomes	Small sized, 70S ribosomes (50S larger sub-unit and 30S smaller sub-unit)	Large sized, 80S ribosomes (60S larger sub-unit and 40S smaller sub-unit)
Cytoskeleton	Absent	Present
Cell Wall	Peptidoglycan/ Murein/ Sacculus	Cellulose/ Chitin
Cell Membrane	Sterols absent	Sterols present
Cell Division	Binary fission	Mitosis/ Meiosis
Histones	Absent	Present
Composition of Flagella	Flagellin	Tubulin
Example	Bacterial cell, Cells of blue green algae	Plant and Animal cells





TOPIC-2 & 3 » BIOLOGICAL MOLECULES & ENZYMES

COURSE CONTENT

- Introduction to Biological Molecules
- Importance of Water
- Carbohydrates
- Proteins
- Lipids
- Nucleic Acids
- Conjugated Molecules
- Introduction of Enzymes
- Characteristics of Enzymes
- Mechanism of Enzyme Action (Models)
- Factors Affecting the Rate of Enzyme Action
- Enzyme Inhibition
- Feedback Inhibition

INTRODUCTION TO BIOLOGICAL MOLECULES

Biological Molecules in Protoplasm

Early biologists thought that the cell consists of a homogeneous jelly, which they called protoplasm. Today the word protoplasm if used at all is applied in a very general way.

Parts of Protoplasm

- The portion of protoplasm outside the nucleus is called cytoplasm.
- The corresponding material within the nucleus is termed as nucleoplasm.

Composition of Cytoplasm

- The cytoplasm is composed of several types of organelles and a fluid matrix, the cytosol (literally cell solution) in which the organelles reside. The cytosol is a watery solution of salts, sugars, amino acids, proteins fatty acids, nucleotides etc.

		Total Cell Weight	
		Bacterial Cell	Mammalian Cell
1.	Water	70	70
2.	Proteins	15	18
3.	Carbohydrates	3	4
4.	Lipids	2	3
5.	DNA	1	0.25
6.	RNA	6	1.1
7.	Organic molecules (enzymes, hormones, metabolites)	2	2
8.	Inorganic ions (etc.)	1	1

IMPORTANCE OF WATER

Importance

- Water is the **medium of life** and is **most abundant compound** in all organisms.
- It varies from 65 to 89% in different organisms.
- Human tissues contain about 20% water in bone cells and 85% in brain.
- It acts as a lubricant against friction, e.g., **tears** protect the surface of eye from the rubbing of eyelids.
- It acts as fluid cushion around organs that protect them from trauma.
- Biochemical reactions take place in the presence of water.
- It also takes part in many biochemical reactions such as **hydrolysis** of macromolecules.
- It is also used as a **raw material** in reactions like photosynthesis.

Solvent Properties:

- Water is an **excellent solvent** for polar substances due to its dipole nature.
- Almost all the reactions in cells occur in aqueous media even enzymes work in aqueous environment. Ions and molecules **move randomly** and are in a more favorable state to react with other molecules and ions when in solution.
- Molecules which are **insoluble** in water, for example non polar organic molecules like fats help to maintain membranes which make compartments in the cell.

Specific Heat Capacity of Water:

- It is the number of calories required to raise the temperature of 1g of water from 15°C to 16°C is called specific heat capacity. It is **1 calorie** for water.
- Water has great ability to absorb the heat, since most of the heat is used to break hydrogen bonds. Thus it acts as an efficient **temperature stabilizer**

Heat of Vaporization:

- Amount of heat absorbed when 1g of water to change from liquid to gaseous state is called **heat of vaporization.**
- Specific heat of vaporization of **water** is **574 Kcal/ kg**.
- Evaporation of only 2ml out of 1 liter of water lowers the temperature of remaining 998ml by 1°C.
- The advantage of high heat of vaporization of water is that it provides cooling effect to plants and animals.

Ionization of Water

- $H_2O \rightleftharpoons H^+ + OH^-$ it is a reversible reaction.
- At 25°C, the concentration of each H^+ and OH^- ions in pure water is about 10^{-7} **moles/lit.**
- H^+ and OH^- ions take part in many reactions that occur in cell.

CARBOHYDRATES

- Literal meaning "hydrated carbons".
- They are composed of C, H_2, and O_2. Mostly hydrogen and oxygen are found in same ratio as in water (2:1).
- Chemically they are defined as "polyhydroxy aldehydes or ketones or complex substances which on hydrolysis yield polyhydroxy aldehyde or ketone subunits."
- Their **general formula** is $C_x(H_2O)_y$ where 'x' is the whole number from three to many thousands whereas 'y' may be same or different whole number.
- Simple carbohydrates are the main **source of energy** in cell.

- Some carbohydrates are the main **constituents of cell walls** in plants and microorganisms.
- **Examples** are cellulose in wood, cotton and paper, starches present in cereals, root tubers, cane sugar and milk sugar.
- Their **main sources are** green plants, which produce them by photosynthesis. Even all the other compounds of plants are synthesized from carbohydrates.
- Carbohydrates combine with proteins and lipids to form **glycoprotein & glycolipids** respectively. These compounds are collectively called glyco-conjugates.

Major Groups of Carbohydrates

Feature	Monosaccharides	Oligosaccharides	Polysaccharides
Common Name	Simple sugars	Complex sugars	Most complex sugars(Branched or unbranched)
Taste	Sweet	Less sweet	Tasteless
Solubility in water	Easily soluble in water	Less soluble in water	Sparingly soluble in water
Hydrolysis	Cannot be hydrolyzed	Can be hydrolyzed	Can be hydrolyzed
General Formula	$(CH_2O)_n$/ $C_nH_{2n}O_n$/ $C_n(H_2O)_n$	$C_n(H_2O)_{n-1}$ (for disaccharides)	$C_x(H_2O)_y$
Classification	• On the bases of number of carbon atoms e.g. trioses (3C), tetroses (4C), pentoses (5C) etc. • On base of functional group e.g. aldo and keto sugars.	On the bases of monosaccharides released during hydrolysis e g. disaccharides, trisaccharides etc.	On the bases of structural complexity & relation e.g. starch, glycogen, cellulose, dextrin, agar, pectin and chitin.
No. of sugar units	• One	Two Ten	10 ≤ 1000 or above

Monosaccharides

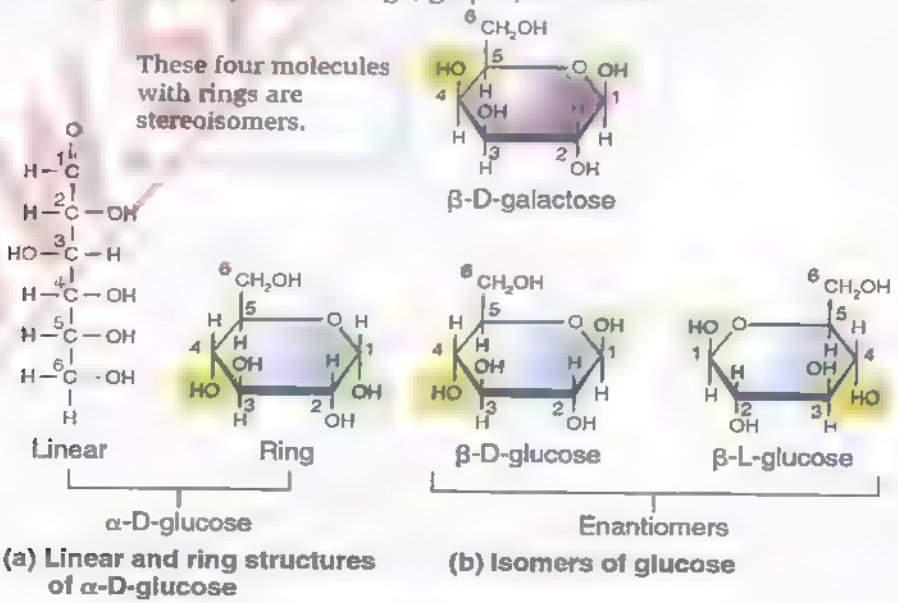
- In nature, monosaccharides with **3 – 7 C atoms** are found.
- All carbon atoms except one have hydroxyl group. This exception is carbon of aldehyde or ketone group.

Atoms					
3 C	Trioses	$C_3H_6O_3$	Glyceraldehyde	Dihydroxyacetone	Intermediates in photosynthesis & respiration
4 C	Tetroses	$C_4H_8O_4$	Erythrose	Erythrulose	Intermediates in photosynthesis in bacteria
5 C	Pentoses	$C_5H_{10}O_5$	Ribose	Ribulose	Ribose is found in RNA while Ribulose is found in Calvin cycle
6 C	Hexoses	$C_6H_{12}O_6$	Glucose	Fructose	Energy source, Polysaccharide formation
7 C	Heptose	$C_7H_{14}O_7$	Glucoheptose	Sedoheptulose	Intermediates in photosynthesis in bacteria

- Most monosaccharide (pentoses & hexoses) form **a ring structure** in solution.
- Furanose is 5 cornered ring while pyranose is 6 cornered ring structures.
- These rings are heterocyclic having oxygen at one corner and carbon at other corners.
- Each pentose and hexose exists in either 'α' or 'β' forms depending upon position of H^+ and OH^- groups at C_1. If OH^- group is found downward at C_1, it is called 'α' sugar and if OH^- group is present upward on C_1 then it is known as 'β' sugar.

Glucose

- It is naturally produced in green plants which take CO_2 from air and H_2O from soil to synthesize glucose.
- Synthesis of **10g of glucose** requires **717.6 Kcal** of solar energy, which in turn is stored in glucose molecule and becomes available in all organisms when it is oxidized in the body.
- Our **blood** contains **0.08% glucose**.
- Starch, cellulose, and glycogen yield glucose on complete hydrolysis.
- In free form, glucose is present in figs, grapes, and dates.



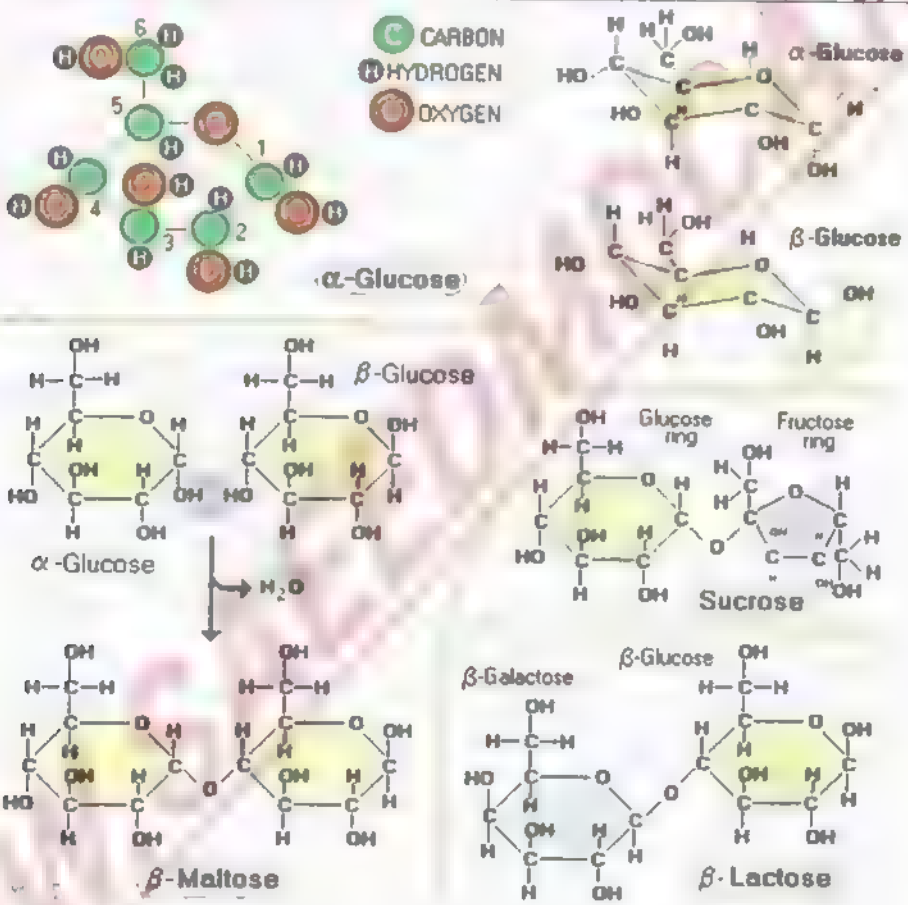
(a) Linear and ring structures of α-D-glucose

(b) Isomers of glucose

Oligosaccharides

- Those oligosaccharides which yield two monosaccharides on hydrolysis are called **disaccharides** and those yielding three are called **trisaccharides.**
- The covalent bond formed between two monosaccharides is called **glycosidic bond.**
- **Maltose, sucrose, and lactose** all are disaccharides. Their general formula is $C_{12}H_{22}O_{11}$.

Disaccharide	Source and Common Name		
Maltose	Candies, Barley, Sweet potatoes, Fruits (Malt Sugar)	Glucose + Glucose	1,4-glycosidic bond
Sucrose	Sugar Cane (Cane Sugar)	Glucose + Fructose	1,2-gycosidic bond
Lactose	Milk (Milk Sugar)	Galactose +Glucose	1,4-glycosidic bond



Reducing and Non-Reducing Sugars

- Sugars which give positive result on **Benedict or Fehling tests** are called reducing sugars These act as reducing agents. They have free aldehyde or free ketone group. All monosaccharides, lactose and maltose are reducing sugars. Ketoses must first tautomerize to aldoses before they act as reducing sugars.
- **Sucrose** is an example of non-reducing sugar.

POINT TO PONDER

Polysaccharides

- They are formed by several monosaccharide units linked together by glycosidic bonds.
- They act as structural components, food and energy stores.
- Examples of polysaccharides include starches, glycogen, cellulose, dextrins, agar, pectin and chitin (N_2-containing polysaccharide).

Classes of Polysaccharides

Feature	Starch	Glycogen (Animal Starch)	Cellulose	Chitin
Organism	Plants, Green Algae	Animal, Fungi, Prokaryotes	Plants, Green Algae (Most abundant carbohydrate). Cotton is pure form of cellulose.	Fungi, Arthropods
Location	Fruits, grains, seeds, tubers.	Most of cells but abundant in liver and muscles.	Main constituent of cell walls.	Cell wall in Fungi, Exoskeleton of Arthropods
Main Function	Main source of carbohydrates for animals.	Chief storage form in animals.	Main constituent of cell wall of plants.	Protection
Result of Hydrolysis	α-Glucose molecules	α-Glucose molecules	β-Glucose molecules (α-amylase in our gut cannot digest it)	N-acetyl β-glucosamine
Solubility	Amylose: Soluble in hot water Amylopectin. Insoluble in hot or cold water	Insoluble in water	Highly insoluble in water	Insoluble in water
Branching	Amylose: Un-branched Amylopectin. Branched	Branched (More than Amylopectin)	Un-branched	Un-branched
Glycosidic Linkage	Amylose: α–1, 4 Amylopectin: $\alpha-1,4$ & $\alpha-1,6$	α 1,4 & α 1,6	β - 1,4	$\beta-1,4$
Iodine Test	Blue colour with iodine	Red colour with iodine	No colour change on iodine test	No colour change on iodine test

Tests for Carbohydrates

- Benedict or Fehling test to detect reducing and Non-reducing sugars.
- Iodine test is used to detect different types of polysaccharides.

POINT TO PONDER

PROTEINS

- They are the **most abundant organic compounds** found in cells and comprising over 50% of their total dry weight.
- Proteins are polymers of amino acids, the compounds containing **C, N_2, O_2, and H_2** and few amino acids contains S.
- A protein may consist of a single polypeptide or more than one

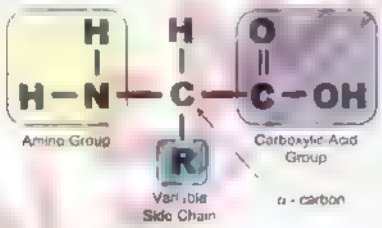
Example	Major Functions
Building Structures	Proteins are involved in building many structures e.g. collagen
Enzymes	Catalyze chemical reactions and control whole metabolism of cell.
Hormones	Regulate metabolic processes.
Transport Proteins	Carrier protein that transports O_2 (Hemoglobin), lipids, metal ions etc.
Antibodies	Defend the body against pathogenic attack.
Clotting Proteins	Prevent loss of blood after injury.
Mitotic Apparatus	Helps in movement of chromosomes during anaphase of cell division.

Amino Acids

- About **170** amino acids have been found in cells and tissues.
- Out of 170 types only **25** are constituents of proteins.
- Most of the proteins are, however, made of **20** types of amino acids.

Basic Structure of Amino Acid

- An amino acid is an organic compound containing an amino group and a carboxyl group, attached to central carbon called alpha carbon.

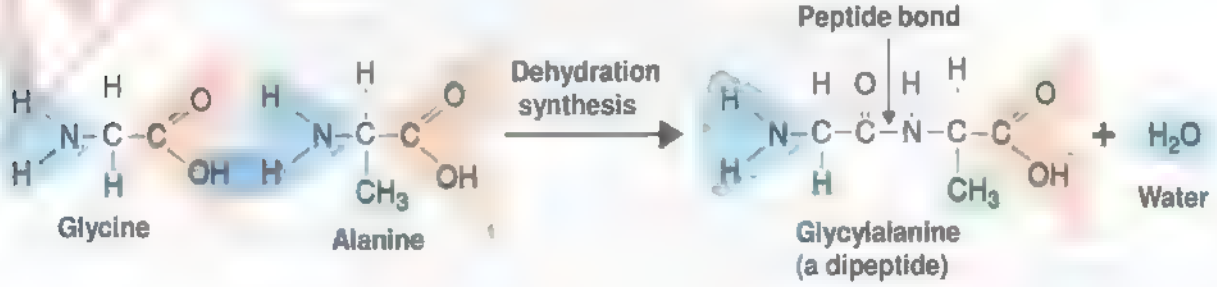


POINT TO PONDER

What are essential & non-essential amino acids

Peptide Bond Formation

- Amino acids link together to form a polypeptide molecule.
- Two amino acids combine together via a peptide bond to form a dipeptide, e.g., Glycine and Alanine chemically interact with each other to form **glycylalanine**. Similarly, tri, tetra and pentapeptides can be formed. Naturally, this dehydration condensation reaction occurs during translation of mRNA.



- In this figure, -OH of carboxyl group of Glycine combines with H^+ of amino group of Alanine releasing water molecule and forming C-N link called **peptide bond**.

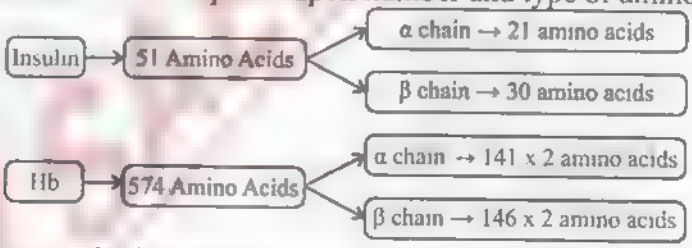
Structure of Proteins

There are four levels of organization of protein molecules.

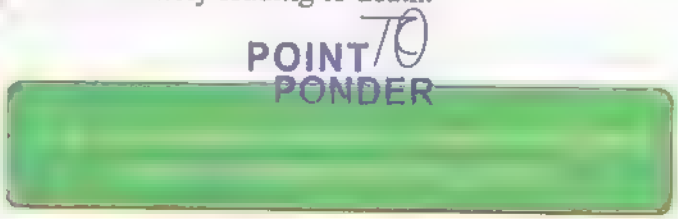
Feature	Primary	Secondary	Tertiary	Quaternary
Information	Number and sequence of amino acids in protein molecule.	Structural conformation (form or shape) e.g. coil or helix	Bending and folding of polypeptide chain and forming regular 3-D globular shape.	Aggregation and held together by hydrophobic interactions.
Bonds	Peptide bond disulphide bridges	Hydrogen	Ionic, Hydrogen, Disulphide (-S-S-)	Hydrogen, Ionic bonds, Hydrophobic interactions
Example	Insulin	Alpha helix (α-helix), β-pleated sheet	Human myoglobin	Hemoglobin

Primary Structure

- **F. Sanger** was the first scientist who determined the sequence of amino acids in a protein molecule.
- The sequence of amino acids in a protein molecule is determined by the order of nucleotides in the DNA.
- It is shown by all proteins at the time of their synthesis on ribosome surface.
- The size of protein molecule depends upon number and type of amino acids comprising it.

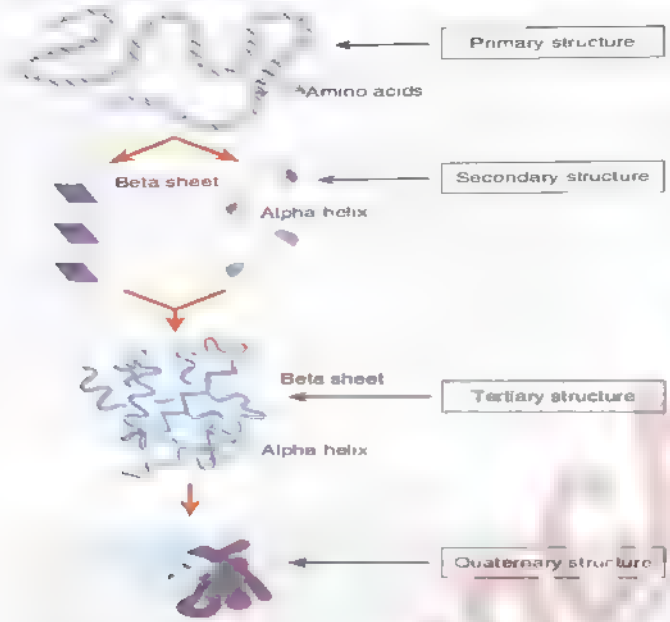


- A change in even a single amino acid, results in the failure of that protein, which may even lead to death, e.g., replacement of glutamic acid by valine in hemoglobin molecule results in formation of sickle hemoglobin, which fails to carry oxygen, the characteristic of sickle cell anemia ultimately leading to death.



Secondary Structure

- α- helix and β- pleated sheets are its examples.
- **α- helix** is a very uniform geometric structure with **3.6 amino acids** in each turn of the helix.
- **B-pleated sheet** is formed by the folding back of the polypeptide.



Tertiary Structure

In aqueous environment, the most stable tertiary conformation is that in which hydrophobic amino acids are buried inside while the hydrophilic amino acids are on the surface of molecule.

Quaternary Structure

In many highly complex proteins, polypeptide tertiary chains are aggregated and held together by hydrophobic interactions. This specific arrangement is the quaternary structure of proteins.

POINT TO PONDER

Classification of Proteins

Feature	Fibrous Protein	Globular Protein
Shape	Fibrils form	Spherical or ellipsoidal
Structural organization	Secondary	Tertiary or quaternary
Solubility in aqueous media	Insoluble in aqueous media	Soluble in aqueous media
Crystal Nature	Non-crystalline	Can be crystallized
Elasticity	Elastic in nature	Inelastic in nature
Role	Play structural role	Play functional role
Stability	Stable	Unstable
Examples	Silk fibers, myosin, fibrin, keratin	Enzymes, antibodies, proteinaceous hormones, hemoglobin.

POINT TO PONDER

fibrous proteins are mor
globular proteins while th
structural ro

Important Stru ure Pro in	
Collagen	Bone and cartilage matrix
Elastin	Elasticity to tendon and ligaments
Keratin	Protective coverings e g. hair, nails, quills, feathers, horns and beaks
Histone	Chromosome
Enzymes	Control metabolism
Hormones	Regulation of physiological activities
Antibodies	Immunity
Haemoglobin	Transport of Gases
Fibrinogen	Blood Clotting
Ovalbumin	Storage of amino acids in eggs
Casein	Storage of amino acids in milk

LIPIDS

- Lipids are a heterogeneous group of compounds related to fatty acids.
- They are **insoluble in water** but **soluble in organic solvents** like ether, alcohol, chloroform and benzenes.
- Their hydrophobic nature makes them best suited to be a **structural component of cell membranes**.
- Lipids store **double the amount of energy** as compared to same amount of carbohydrates because of high proportion of C-H bonds and very low proportion of oxygen.
- May act as **insulating layer** e.g., waxes in exoskeleton of insects, and cutin which is an additional protective layer on the cuticle of epidermis of some plant organs. E.g. leaves, fruits, seeds.

Acylglycerols

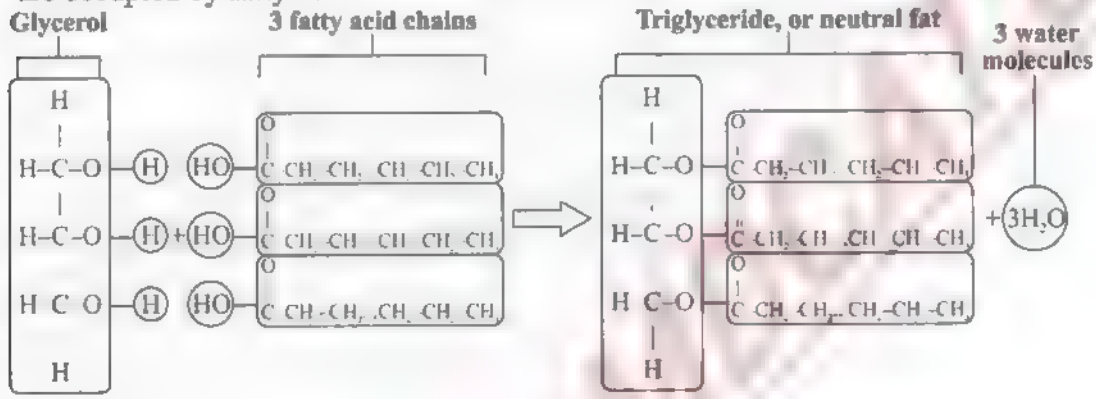
- These are esters of glycerol and fatty acids.

- An ester is the compound produced as the result of a chemical reaction of an alcohol with acid and a water molecule is released. Such a reaction is called esterification.

$$\text{Fatty Acid} + \text{Glycerol} \xrightarrow{\text{Esterification}} \text{Acylglycerol} + H_2O$$

$$C_2H_5OH + HOOCCH_3 \longrightarrow C_2H_5OCOCH_3 + H_2O$$

- Glycerol is a tri-hydroxy alcohol which contains three carbons, each bearing an OH group.
- When three fatty acids combine with one glycerol, a triacylglycerol (triglyceride) is formed. Triacylglycerols are also called neutral lipids as all three OH groups of glycerol are occupied by fatty acids.



Fatty Acid

- A fatty acid is an organic compound containing one carboxylic acid group attached to a hydrocarbon.
- Fatty acids contain even number of carbon atoms (2-30). Each fatty acid is represented as R-COOH, where R is hydrocarbon tail.
- Solubility of fatty acids in organic solvents, hydrophobic nature and melting points depend upon number of carbon atoms and number of double bonds.
- Fatty acids are either saturated or unsaturated.
- Specific gravity 0.8

Saturated fatty Acid	Unsaturated Fatty Acid
No double bonds between carbon atoms	Upto six double bonds
Straight chain	Ringed /Branched
Solid at room temperature	Liquid at room temperature
Fats	Oils
Animals	Plants
	More useful for living things.

Fatty acid	Type	No. of Carbon	Source	Melting Point
Acetic acid	Saturated	2	Vinegar	16.6°C
Butyric acid	Saturated	4	Butter	-8°C
Palmitic acid	Saturated	16	Palm tree	63.1°C
Oleic acid	Mono-unsaturated	18	Olives	4°C

Waxes

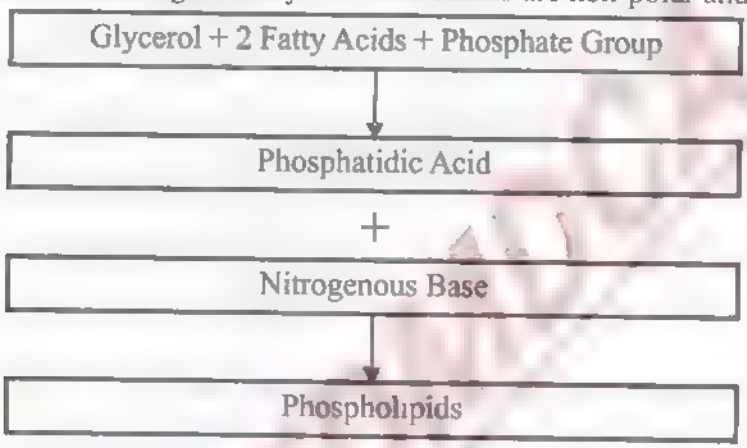
- Chemically, waxes are mixtures of long chain alkanes (with odd number of carbons ranging from C_{25} to C_{35}) and alcohol, ketones and esters of long chain fatty acids

- Waxes are widespread as protective coatings on fruits and leaves. These protect plants from water loss and abrasive damage.
- They also provide water barrier for insects, birds and animals such as sheep.

Phospholipids

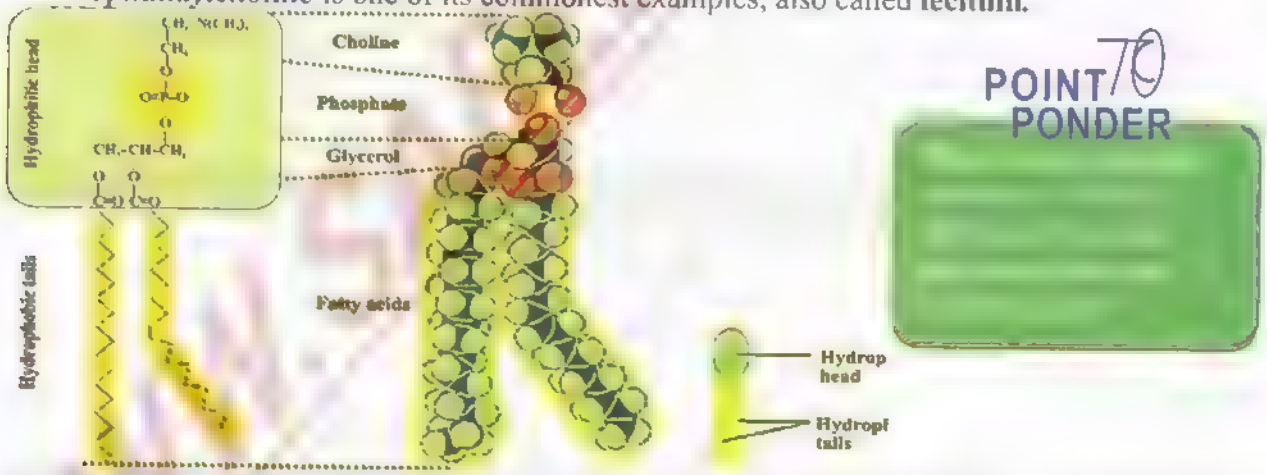
Composition

- They are the derivatives of **phosphatidic acid** by addition of one of the nitrogenous base.
- One end of phospholipid molecule (head), containing the phosphate group and nitrogenous compound is polar and hydrophilic.
- Other end (tail) containing the fatty acid side chains are non-polar and hydrophobic.



Example

- ***Phophatidylcholine*** is one of its commonest examples, also called **lecithin.**



POINT TO PONDER

Function

- They are frequently associated with **biological membranes** and form lipid bilayer.

Terpenoids

- Terpenoids are a very large and important group of compounds which are made up of simple repeating units, called **isoprenoid units**.
- This unit by condensation in different way gives rise to compounds such as rubber, carotenoids, steroids, terpenes etc.

NUCLEIC ACIDS

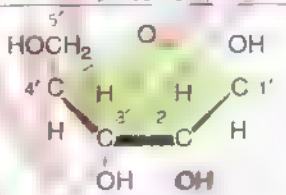
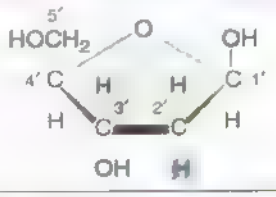
F. Miescher	Nucleic acid in nuclei of pus cells
P. A. Levene	Basic structure of nucleic acids
E. Chargaff	Ratio of different bases present in DNA molecule
M. Wilkins & R. Franklin	X-Ray diffraction analysis of DNA
J.D. Watson & F. Crick	Scale model of DNA Semi-conservative replication of DNA
F. Griffith	Transformation, First evidence of DNA as hereditary material
Avery, MacLeod & McCarty	DNA as transforming principle
A. Hershey & M. Chase	Confirmative evidence of DNA as hereditary material
Meselson& Stahl	Confirmation of semi-conservation replication of DNA
M. Nirenberg, P. Leder and H. G. Khorana	Testing of 64 codons
T. Okazaki	Okazaki fragments during DNA replication

- Nucleic acid was first isolated by **F. Miescher** from nuclei of pus cells (White blood cells).
- They are called nucleic acid, since they were first isolated from nuclei and are acidic in nature.
- Nucleic acids are polymers of **nucleotides.**
- There are two types of nucleic acid: DNA and RNA. Both are linear unbranched polymers.

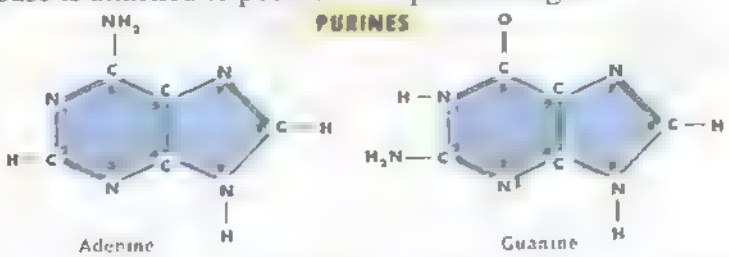
Composition of Nucleotide

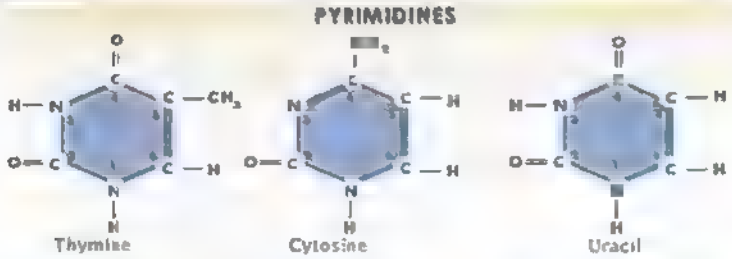
- Each nucleotide is made of 3 components:

1. A 5-carbon monosaccharide (a pentose sugar). It is ribose in ribonucleotide and deoxyribose in deoxyribonucleotide.

$C_5H_{10}O_5$	$C_5H_{10}O_4$
	

2. A nitrogen containing base. Nitrogenous bases are of two types, single ringed pyrimidines (C, T & U) and double ringed purines (A & G). In a typical nucleotide, nitrogenous base is attached to position 1 of pentose sugar.

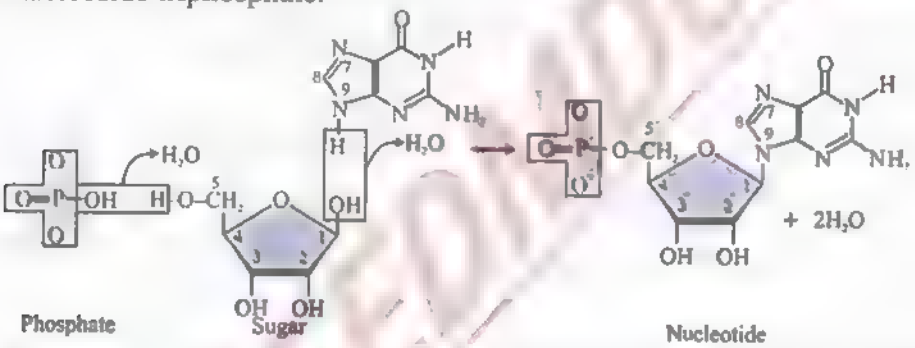




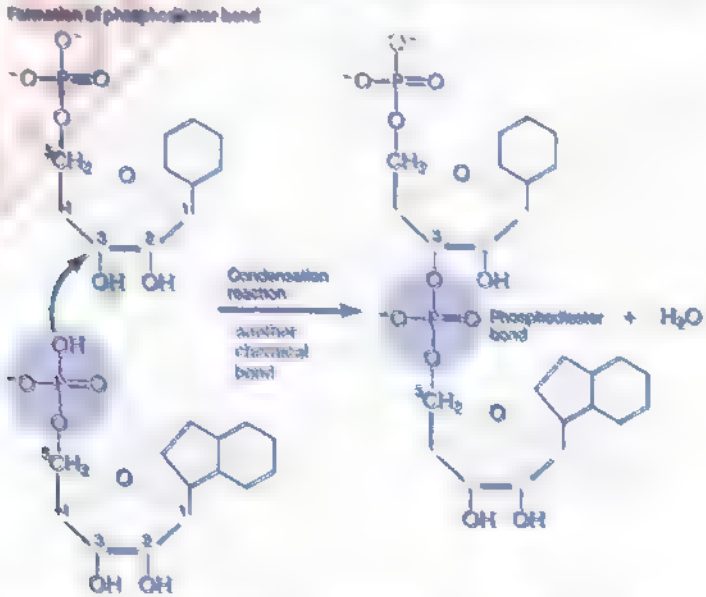
3. A phosphoric acid (H_3PO_4). It has ability to develop ester linkage with OH^- group of pentose sugar. It is attached to carbon at position 5 of pentose sugar. Phosphoric acid provides acidic properties to nucleic acid.

Formation of Nucleotide

- Base + Sugar → Nucleoside
- Nucleoside + Phosphoric acid → Nucleotide
- A nucleotide with one phosphoric acid is called nucleoside monophosphate, with two phosphoric acids is called nucleoside diphosphate and with three phosphoric acids is called nucleoside triphosphate.

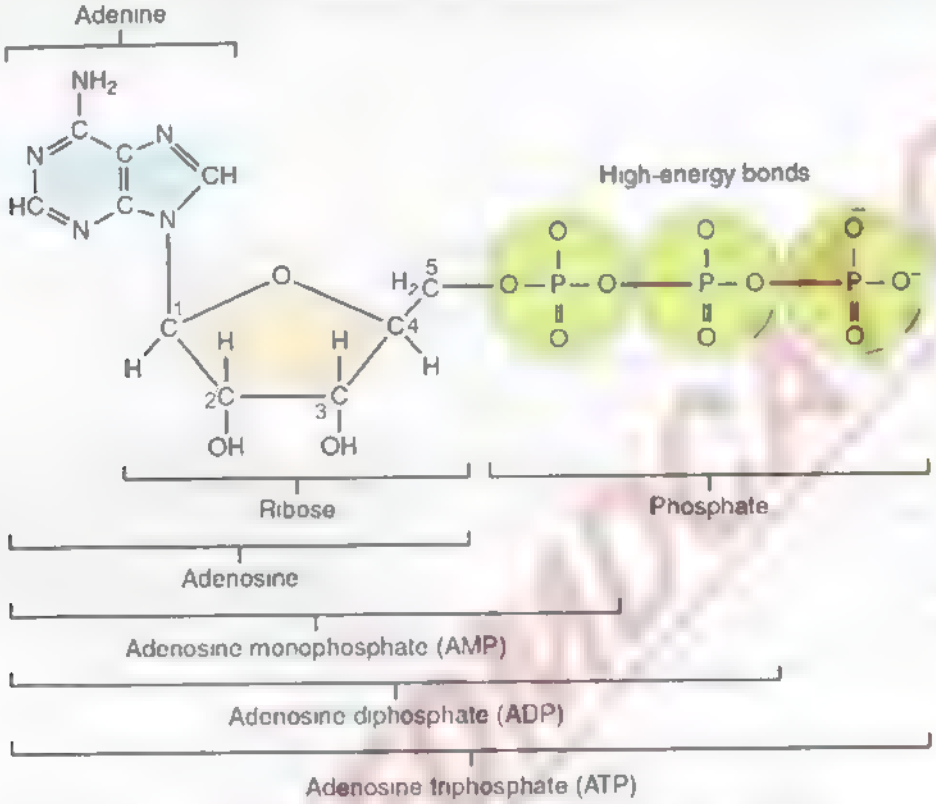


- 2 nucleotides in DNA or RNA are connected through condensation reaction by **phosphodiester linkage.**
- Polynucleotides have a free 5' phosphate group at one end and a free 3' hydroxyl group at the other end. By convention, these sequences are named from 5' to 3'.



Important Examples of Nucleotides

- ATP is an imported mononucleotide used as an energy currency by the cell.



- NAD (Nicotine amide adenine dinucleotide), NADP (Nicotinamide adenine dinucleotide phosphate) and FAD (Flavin adenine dinucleotide) are important dinucleotides and important co-enzyme in several oxidation-reduction reactions in the cell.

POINT TO PONDER

Do you know which vitamin is involved in formation of NAD^+?

Deoxyribonucleic Acid (DNA)

- DNA is hereditary material. It controls the properties and potential activities of a cell.

Nucleotide of DNA

Nitrogenous Base	Nucleoside (Deoxyribose + Base)	Nucleotides (Nucleoside + Phosphoric Acid)		
Adenine	d-Adenosine	dAMP	dADP	dATP
Guanine	d-Guanosine	dGMP	dGDP	dGTP
Cytosine	d-Cytidine	dCMP	dCDP	dCTP
Thymine	d-Thymidine	dTMP	dTDP	dTTP

Relative Amounts of Bases in DNA

- In 1951, **Erwin Chargaff** provided data about the ratios of different bases present in a DNA molecule.

- This data suggested that adenine and thymine are equal in ratio and so are guanine & cytosine.
- Similarly, total purines and total pyrimidines are in 1:1 in any DNA molecule.

Source				
Man	30.9	29.4	19.9	19 8
Sheep	29.3	28.3	21.4	21.0
Wheat	27.3	27.1	22.7	22.8
Yeast	31.3	32.9	18.7	17.1

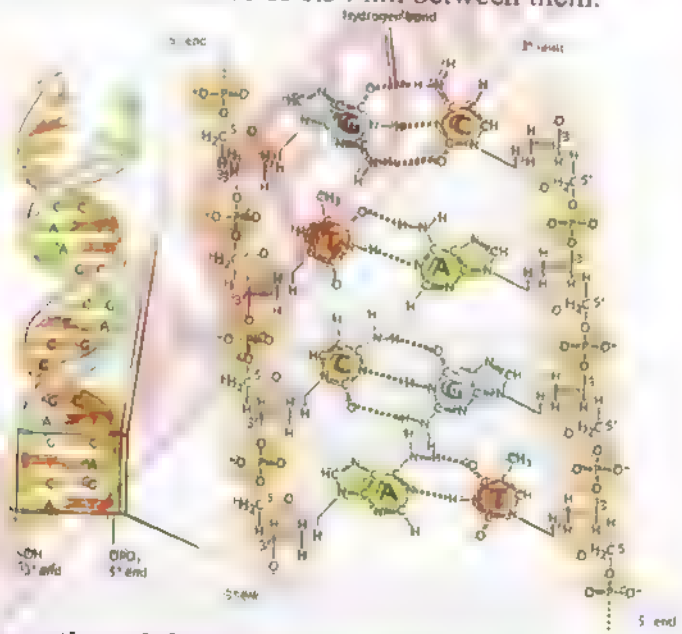
Scale Model of DNA

Maurice Wilkins and Rosalind Franklin described X-ray diffraction analysis of DNA. Watson & Crick presented scale model of DNA. Its salient features are given below:

- DNA is a dual polymer and made of two polynucleotide chains or strands.
- The two strands are coiled round each other in anti-parallel way to form a double helix (duplex).
- The two chains are held together by weak hydrogen bonds. Adenine and thymine are connected by two hydrogen bonds while guanine and cytosine are connected by three hydrogen bonds.

POINT PONDER

- Diameter of DNA double helix is 2nm.
- In **each turn of DNA**, there are about 10 base pairs of about 34 Angstrom units.
- Base pairs are flat with a distance of 0.34 nm between them.



Amount of DNA in Somatic and Germ Cells

	Amount of DNA/Nucleus	Amount of DNA/Nucleus in Picogram in
Red Blood Cells	2.3	3.3
Liver Cells	2.4	3.3
Kidney Cells	2 4	3.3
Sperm Cells	1.3	1.6

Ribonucleic Acid (RNA)

- RNA is polymer of ribonucleotides.
- The RNA molecule occurs as single strand, which may be folded back on itself to give double helical characteristics. In this case, cytosine pairs with guanine and adenine with uracil.
- RNA is synthesized by DNA in a process known as **transcription**.

Nucleotides of RNA

Nitrogenous Base	Nucleoside (Ribose + Base)	Nucleotides (Nucleoside + Phosphoric Acid)		
Adenine	Adenosine	AMP	ADP	ATP
Guanine	Guanosine	GMP	GDP	GTP
Cytosine	Cytidine	CMP	CDP	CTP
Uracil	Uridine	UMP	UDP	UTP

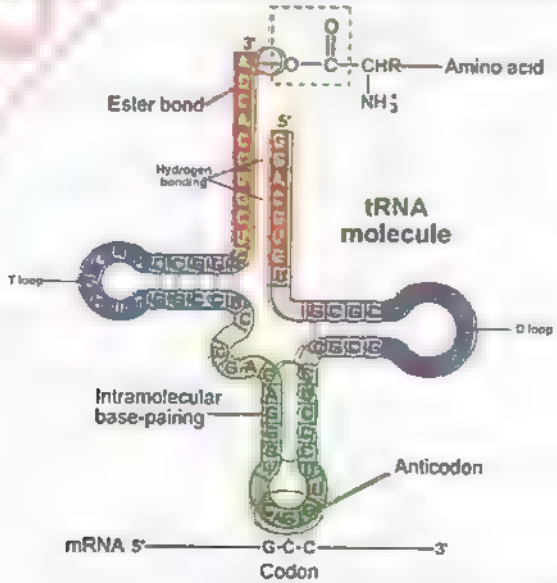
Types of RNA

Messenger RNA (mRNA)

- It takes the genetic message from the nucleus to ribosome in the cytoplasm, where amino acids are arranged to form a specific protein molecule.
- It consists of a single strand of **variable length**.
- Its length depends upon the size of the gene as well as the protein for which it is taking the message. For example, for a molecule of 1000 amino acids, mRNA will have the length of 3000 nucleotides.
- Actually every three nucleotides in mRNA encode a specific amino acid; such triplets of nucleotides along the length of mRNA are called **codons of genetic codes**.

Transfer RNA (tRNA)

- It is **smallest in size**.
- It is a single stranded molecule but it shows a duplex appearance at its some regions.
- It transfers amino acid molecules to the site where peptide chains are being synthesized.
- There is one specific tRNA for each amino acid. So, there are at least 20 kinds of tRNA molecules. tRNA picks amino acids and transfers them to ribosomes.
- Human cells contain about **45 different kinds of tRNA molecules**.



Ribosomal RNA (rRNA)

- It is the **major portion of RNA** in the cell, and may be up to 80% of the total RNA.
- It is transcribed by the genes present on the DNA of several chromosomes.
- These have the largest size among the RNA.
- It acts as machinery for the synthesis of proteins.
- It is strongly associated with the ribosomal proteins where 40 – 50 % of it is present.

	mRNA	tRNA	rRNA
Function	Takes message from DNA to ribosomes	Transfers amino acids to ribosomes	Formation of ribosomes
Length	Single strand of variable length	Length of 75-90 nucleotides	Double helix with constant length
Percentage	3-4%	10-20%	80%

Difference Between DNA and RNA

	DNA	RNA
Nucleotides	Deoxyribonucleotides	Ribonucleotides
Pentose Sugar	Deoxyribose	Ribose
Nitrogenous Bases	A, G, C, T	A, G, C, U
Physical Structure	Double stranded	Single stranded
Location	Chromosome, nuclei, mitochondria and chloroplasts	Nucleolus, ribosomes, cytosol, mitochondria, and chloroplast
Amount	Constant in each cell of species	Variable from cell to cell
Role	Heredity	Protein synthesis

CONJUGATED MOLECULES

Conjugated Molecules

- Two different molecules, belonging to different categories, usually combine together to form conjugated molecules.

Components	Molecule	Role
Carbohydrates + Proteins	Glycoproteins	Cellular secretions, Integral part of biological membranes, Egg albumen. Enzyme, Hormone, Transport protein, Structural protein, Receptors.
Carbohydrates + Lipids	Glycolipids	Integral component of biological membranes and brain. White matter of brain, Myelin sheath of nerve fiber.
Nucleic acid + Histones	Nucleohistones	Chromosome + Regulation of gene expression.
Lipids + Proteins	Lipoproteins	Milk, Blood, Egg yolk membrane, Cell nucleus, Chloroplast of plant, Bacterial antigen and viruses, Cutin: In cuticle Ruber: Wall of cork cell.

INTRODUCTION OF ENZYMES

Enzymes are biological molecules (proteins) which catalyze a biochemical reaction and remain unchanged after completion of reaction.

Without enzymes, reactions are possible but they would proceed at very low speed making life impossible.

Composition

- Enzymes are **globular proteins** made of one or more polypeptide chains having tertiary conformation.
- This protein part is made up of **hundreds of amino acids**. These enzymes have tertiary or quaternary structure.
- Most of the amino acids maintain its globular shape while few are involved in catalysis.
- **Active site** is a charge bearing cavity of enzyme having two regions i.e. **binding site and catalytic sites.** Shape of the active site is designed according to the substrate.
- Binding site is involved in recognition and binding of substrate with enzyme.
- Catalytic site is involved in transformation of enzyme-substrate complex into enzyme and product.

Cofactor

- **Non-protein part** of enzyme that is required for its proper functioning is called **co-factor.**
- Cofactor acts as bridge between enzyme and substrate. It also acts as source of chemical energy for catalysis.
- Such an inorganic cofactor that is detachable is called activator e.g. metal ions like Fe^{+2}, Mg^{+2}, Cu^{+2}, Zn^{+2} etc.
- If a cofactor is organic and loosely attached to the protein part, it is known as **coenzyme.** Coenzymes are the derivatives of vitamins. For example, ATP, NAD^{+} and FAD^{1} are common coenzymes.
- If a cofactor or non-protein part is covalently bound to the protein part, it is called a **prosthetic group.** It is permanently attached to enzyme. For example, cytochrome is prosthetic group of cytochrome oxidase.
- An activated enzyme consisting of polypeptide chain and a cofactor is known as **holoenzyme.**
- An enzyme with its coenzyme or prosthetic group has been removed is called apoenzyme.

CHARACTERISTICS OF ENZYMES

- Enzymes are biological molecules which catalyze a biochemical reaction and remain unchanged after completion of reaction.
- All enzymes are globular proteins, having specific chemical composition due to their component amino acids and specific shape.
- Even small amount of them can tremendously increase the efficacy of a biochemical reaction.
- They are specific for each type of a reaction or group of related reactions.
- Their presence **does not affect the nature or properties** of end products.
- They **lower the activation energy** of the reactants.
- They are sensitive to even a minor change in pH, temperature and substrate concentration.

- They **require aqueous media** for their activity.
- Some may require co- factor for their proper functioning.
- Some enzymes are potentially damaging, if they are manufactured in their active form.

MECHANISM OF ENZYME ACTION (MODELS)

Mechanism

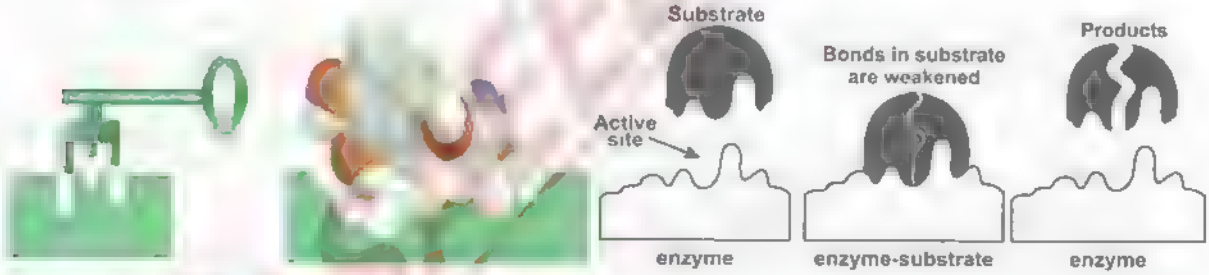
E+S → ES Complex → EP Complex → E+P

- The active site of an enzyme is a **three-dimensional cavity bearing a specific charge** by which the enzyme reacts with its substrate.
- The active site is made of two definite regions i.e. binding site & a catalytic site.
- Binding site helps the enzyme in the recognition and binding of the proper substrate to produce an **ES complex.**
- Activated catalytic site catalyzes the transformation of the substrate into product/s.
- Formation of ES complex activates the catalytic site.

Models

Lock and Key Model

- **Emil Fischer** (1890) proposed Lock and Key model.
- As one specific key can open a specific lock, in the same manner a specific enzyme can transform a specific substrate into product/s.
- According to this model, active site is a **rigid structure** and thus there is **no modification or flexibility** in the active site before, during or after the enzyme action.
- It was proved later on that all the chemical reactions cannot be explained on the basis of this model.



Induce Fit Model

- D. Koshland (1959) proposed Induce Fit Model.
- It is the **modified form of Lock and Key model.**
- It states that when a substrate combines with an enzyme, it **induces changes** in the enzyme structure. This change in the structure allows enzyme to carry out its catalytic activity more effectively.
- Enzymes which follow induce fit mechanism are called **regulatory** or **allosteric enzymes.**

FACTORS AFFECTING THE RATE OF ENZYME ACTION

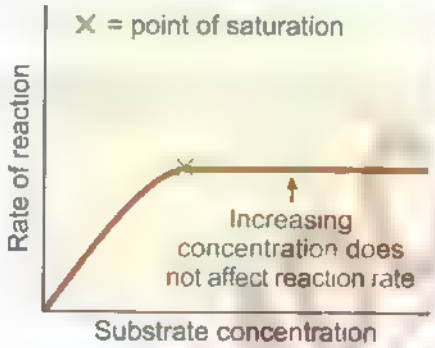
Enzyme Concentration

- Rate of reaction is directly proportional to amount of enzyme present, which in turn determines the number of available active sites for that particular catalytic reaction.
- If substrate concentration is unlimited and amount of an enzyme is increased by two-fold the reaction rate will be doubled.

- However, after a certain limiting concentration, the rate of the reaction will no longer depend upon this increase.

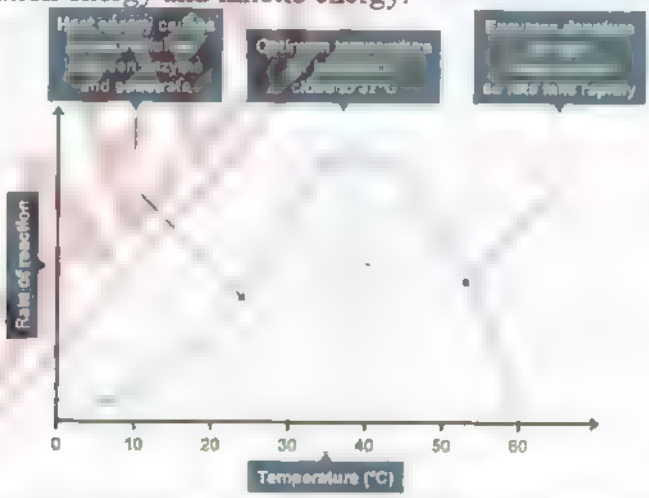
Substrate Concentration

- The rate of an enzyme controlled reaction is directly proportional to the substrate concentration provided that active sites on the enzyme are available.
- At higher concentration of enzyme, increase in substrate concentration increases reaction velocity. Reaction reaches to maximum at equilibrium state.
- When all active sites are occupied by substrate and no more available, this state is called state of saturation.



Temperature

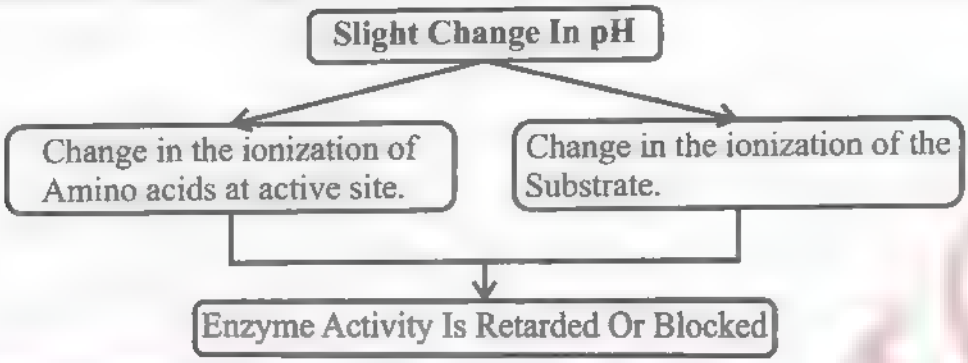
- Heating increases molecular motions. Thus, the molecules of substrate and enzyme move more quickly, so probability of reactions to occur is increased.
- Heat provides activation energy and kinetic energy.



- The rate of an enzyme controlled reaction increases with an increase in temperature up to certain limits. Increase of 10°C in temperature doubles the rate of reaction.
- Optimum temperature is the temperature at which an enzyme works at its maximum rate e.g., for enzymes of our body 37°C is the optimum temperature.
- Increase in temperature above optimum value increases the vibrations of atoms in enzyme. If vibrations become too violent, globular structure essential for enzyme activity is lost and the enzyme is said to be denatured.
- If temperature is reduced to near or below freezing point, enzymes are inactivated.

pH Value

- Optimum pH is the range of pH at which an enzyme functions most effectively.

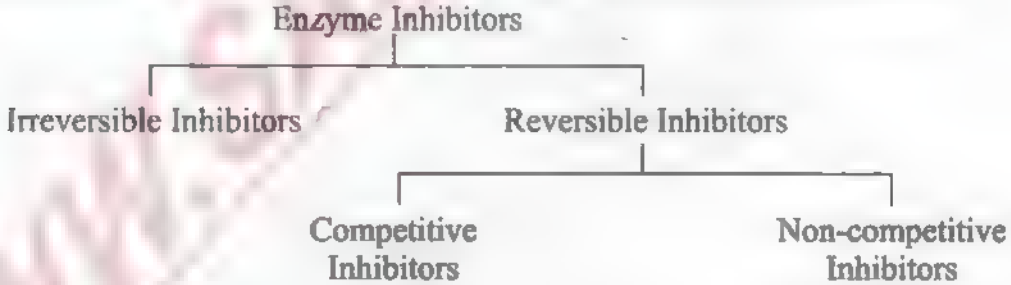


- Extreme changes in pH cause the bonds in the enzyme to break, resulting in the enzyme denaturation.

Enzyme	Function	Optimum pH Value
Pepsin	Digestion of proteins	2.00
Sucrase	Hydrolysis of sucrose	4.50
Enterokinase	Activation of trypsinogen	5.50
Salivary Amylase	Digestion of carbohydrate	6.80
Catalase	Decomposition of H_2O_2	7.60
Chymotrypsin	Involved in proteolysis	7.00-8.00
Pancreatic lipase	Hydrolysis of fats	9.00
Arginase	Catalysis of arginine into urea	9.70

ENZYME INHIBITION

- An inhibitor is a chemical substance which can react (in place of substrate) with the enzyme but is not transformed into product s and thus blocks the active site temporarily or permanently.
- Examples include **cyanide, antibiotics, anti-metabolites and some drugs**.
- They are of two types of inhibitors i e. reversible and irreversible inhibitors.



Irreversible Inhibitor

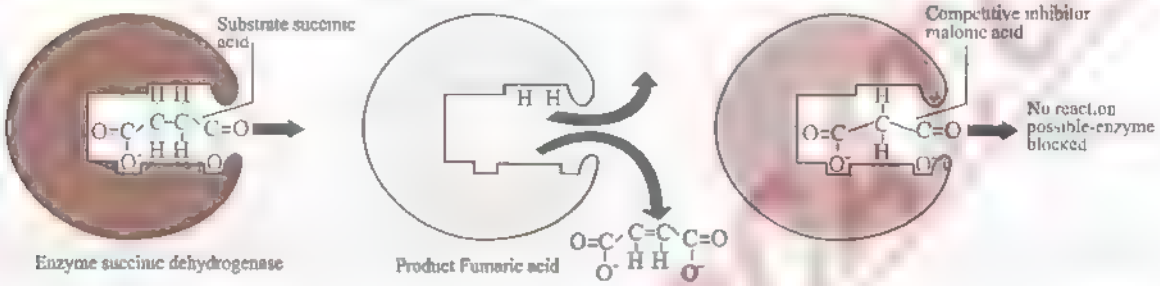
- They occupy the active sites by forming covalent bonds or they may physically block the active sites and they check the reaction rate by occupying the active sites.
- They destroy enzyme by altering the shape so that the substrate cannot bond to the active site.
- Examples of irreversible non-competitive inhibitors are **cyanides and ions of heavy metals.**

Reversible Inhibitors

- They form weak linkages with the enzyme.
- Their effect can be neutralized, completely or partly by increase in the concentration of substrate.
- There are two types of reversible inhibitors i.e. competitive and non-competitive.

Competitive Inhibitors

- Competitive inhibitors are structurally similar to the substrate, hence can bind to the active site but can't activate the catalytic site, thus no products are formed.
- Competitive inhibition is usually temporary.
- Level of inhibition depends upon relative concentrations of substrate and inhibitor.
- This type of inhibition can be reversed by increasing concentration of substrate.

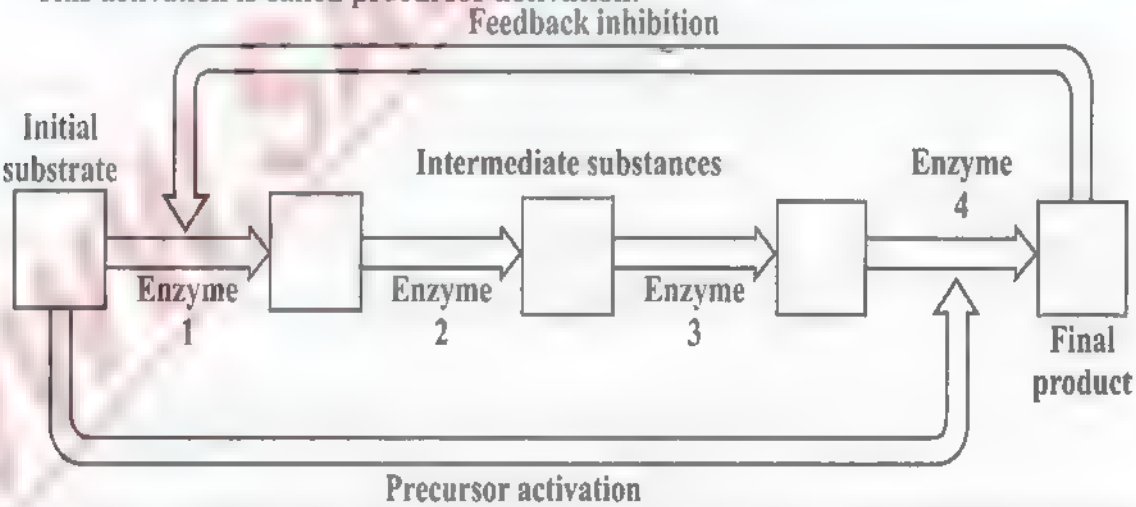


Non-Competitive Inhibitor

- Non- competitive inhibitors bind with the enzyme at the site other than active site. The other binding site of enzyme is called allosteric site.
- Structure of enzyme is altered so that even if a genuine substrate binds the active site, catalysis fails to take place.
- Feedback inhibition is an example of reversible non-competitive inhibition

FEEDBACK INHIBITION

- Activity of enzymes in a cell can be regulated by its products. When the activity of an enzyme is inhibited by its own product, it is called **feedback inhibition** or end product inhibition.
- Similarly, increase in concentration of substrate can cause increase in rate of reaction. This activation is called **precursor activation**.



Typically, **feedback** loop can be divided into two main types: **positive feedback** loops, in which a change in a given direction causes additional change in the same direction, and **negative feedback** loops, in which a change in a given direction causes change in the opposite direction.

TOPIC-4 » BIOENERGETICS

COURSE CONTENT

- Photosynthesis
- Role of Light and Photosynthetic Pigments
- Role of Water and CO_2
- Light Dependent Stage (Production of ATP via ETC\Chemiosmosis)
- Light Independent Stage (Calvin Cycle)
- Cellular Respiration (Aerobic and Anaerobic Reactions)
- Glycolysis
- Pyruvic Acid Oxidation, Krebs cycle
- Respiratory Chain/Electron Transport Chain and Oxidative Phosphorylation

PHOTOSYNTHESIS

Photosynthesis can be defined as the process in which energy poor inorganic oxidized compounds of carbon (CO_2) and hydrogen (mainly H_2O) are reduced to energy rich carbohydrate i.e. glucose (sugar) using the light energy that is absorbed and converted into chemical energy by chlorophyll and some other photosynthetic pigments.

Photosynthetic Reactants and Products

Consider the following equation of photosynthesis;

$$6CO_2 + 12H_2O + \text{Light} \longrightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

This equation shows that carbon dioxide, water and light are the reactants while glucose and oxygen are the products. Water appears on both sides of the equation because water is used as reactant in some reactions and released as product in other. However, because there is no net yield of H_2O, we can simplify the summary equation of photosynthesis for purpose of discussion:

$$6CO_2 + 6H_2O + \text{Light} \longrightarrow C_6H_{12}O_6 + 6O_2$$

Relation between Photosynthesis and Respiration

- Chemical equation of photosynthesis is almost exactly opposite to the overall equation of aerobic respiration ($C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$).
- Photosynthesis uses the products of respiration and respiration uses the products of photosynthesis.
- Photosynthesis occurs only during daytime, whereas respiration goes on day and night.

Light Variations and Compensation Point

- During darkness, leaves and other actively metabolizing cells respire and utilize oxygen and release carbon dioxide.
- At dawn and dusk, when light intensity is low, the rate of photosynthesis and respiration may for a short time, equal one another. Thus oxygen released from photosynthesis is just the amount required for cellular respiration. Also the carbon dioxide released by respiration just equals the quantity required by photosynthesizing cells.

  At this moment there is no net gas exchange between the leaves and the atmosphere. This is termed as **compensation point.**

  As the light intensity increases, so does the rate of photosynthesis and hence the requirement for more carbon dioxide increases which respiration alone cannot supply.

Similarly, the oxygen produced during photosynthesis is more than the need of the respiring cells, so the result is the net release of oxygen coupled with the uptake of carbon dioxide.

ROLE OF LIGHT AND PHOTOSYNTHETIC PIGMENTS

Role of Light and Types of Spectra

- Photosynthetic pigments are the substances that absorb **visible light** (380-750 nm wavelengths).
- All the wavelengths that are absorbed by the pigments are disappeared.
- Light is form of energy called electromagnetic energy or radiations. It behaves as waves as well as sort of particles called **photons**.
- The radiations most important for life are the visible light that ranges from about **380 to 750 nm wavelength.**
- Not all the light falling on leaf is absorbed. Only about 1% of the light falling on the leaf surface is absorbed, the rest is reflected or transmitted.

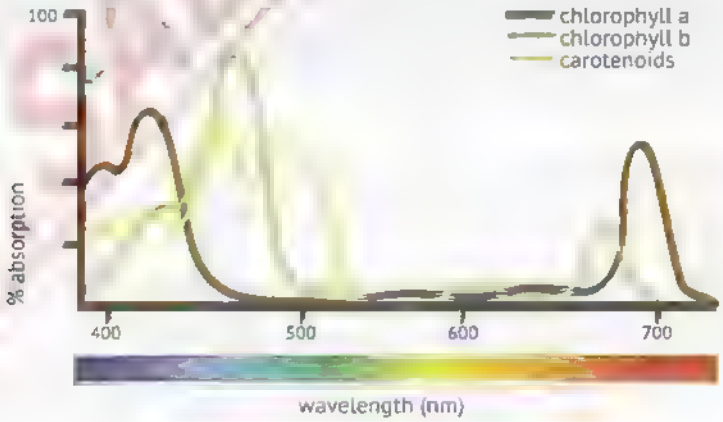
Spectrum of Light for Plants

There are two types of spectrum:

- Absorption spectrum
- Action spectrum

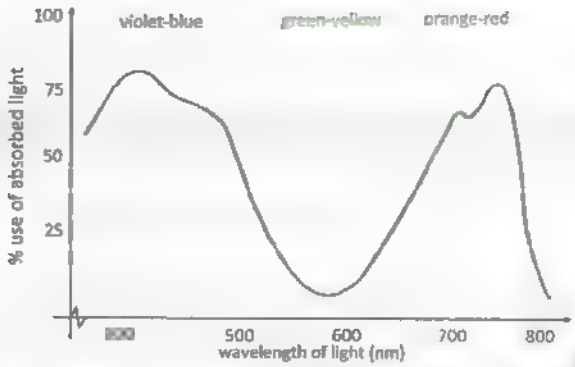
Absorption Spectrum

- Graph showing relative absorption of different wavelengths of light by different photosynthetic pigments is called absorption spectrum.
- Absorption spectrum of chlorophylls indicates that absorption is maximum in blue and red parts of the spectrum, two absorption peaks being at around 430 nm and 670 nm respectively.
- Absorption peaks of carotenoids are different from those of chlorophylls.



Action Spectrum

- Graph showing relative effectiveness of different wavelengths of light in driving photosynthesis is called action spectrum of photosynthesis.
- The first action spectrum was obtained by German biologist T.W. Engelmann in 1883. He worked on *Spirogyra*.
- Action spectrum can be obtained by illuminating plant with light of different wavelengths and then estimating relative CO_2 consumption or oxygen release during photosynthesis.



Comparison of Absorption and Action Spectra

- Action spectrum of photosynthesis corresponds to absorption spectrum of chlorophyll. The same two peaks and the valley are obtained for absorption of light as well as for CO_2 consumption.
- However, the action spectrum of photosynthesis does not parallel the absorption spectrum of chlorophyll exactly.
- Photosynthesis in the most absorbed range is more than the absorption itself.
- Likewise, photosynthesis in 500-600 nm (including green light) is more than the absorption of green light by chlorophylls. This difference occurs because of the accessory pigments, carotenoids.
- When equal intensities of light are given, there is more photosynthesis in red than in blue part of spectrum.

Feature	Absorption Spectrum	Action Spectrum
Peaks	Narrow	Broader
Valley	Broader and deep	Narrow and not deep

Role of Photosynthetic Pigments

Chlorophylls

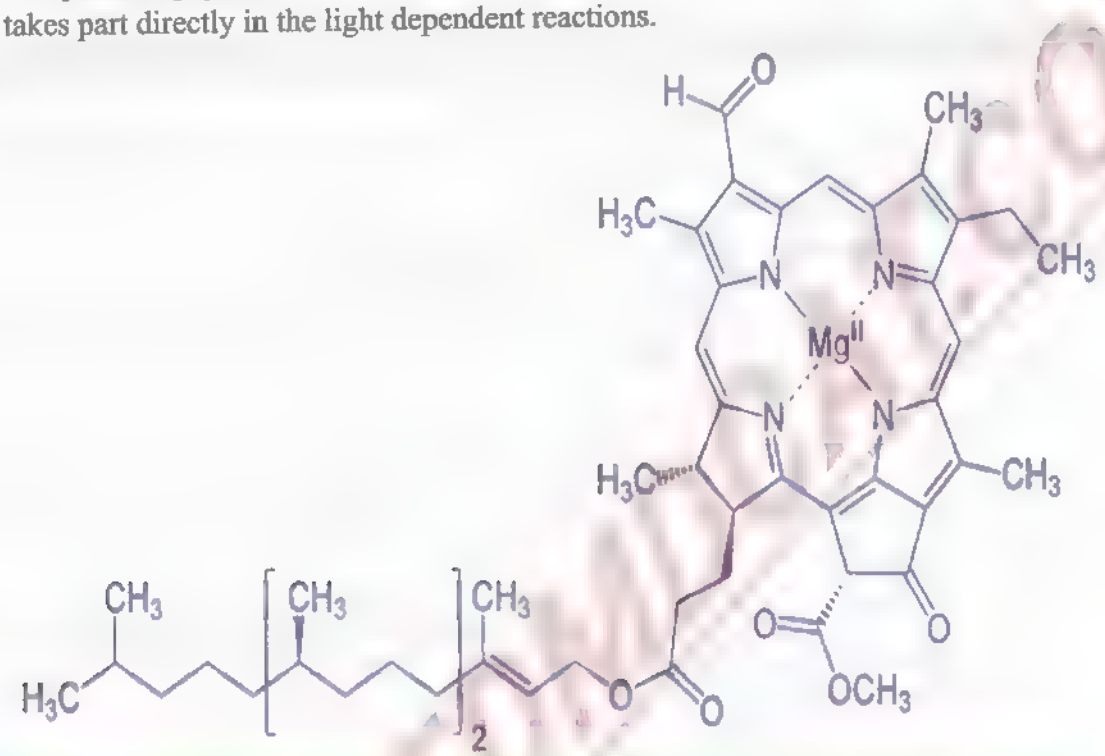
- They are **main photosynthetic pigments of plants**.
- They are **insoluble in water** but are **soluble in organic solvents** like carbon tetrachloride, alcohol etc.
- **Chlorophyll 'a', 'b', 'c' and 'd'** are found in eukaryotic photosynthetic plants and algae.
- **Bacteriochlorophylls** are found in photosynthetic bacteria.
- They mainly **absorb violet-blue and orange-red wavelengths.** Green, yellow and indigo wavelengths are least absorbed by chlorophylls and transmitted or reflected.

Structure

- A chlorophyll molecule has two parts i e. **hydrophilic head** and a **hydrophobic hydrocarbon tail.**
- **Hydrophilic head** is flat, square, light absorbing complex porphyrin ring or tetrapyrrole ring structure containing magnesium as central metal ion, which is coordinated with nitrogen.
- **Hydrophobic hydrocarbon tail** is long, anchoring phytol ($C_{20}H_{39}$). The chlorophyll molecule is embedded in the hydrophobic core of thylakoid membrane by this tail.

Chlorophyll 'a' and 'b'

- Of all the chlorophylls, chlorophyll a is the most abundant and the most important photosynthetic pigment.
- It takes part directly in the light dependent reactions.



Differences between Chlorophyll 'a' and Chlorophyll 'b'

Features		
Molecular Formula	$C_{55}H_{72}O_5N_4Mg$	$C_{55}H_{70}O_6N_4Mg$
Functional Group	$-CH_3$ (methyl group)	-CHO (carbonyl group)
Occurrence	All photosynthetic organisms except photosynthetic bacteria	In association with chlorophyll a in all green plants and green algae
Forms	Differ slightly in their red absorbing peaks e.g. 670,680,690,700 nm	No such different forms
Colour	Blue - green	Yellow- green

Carotenoids-Accessory Pigments

POINT TO PONDER

- Carotenoids are yellow and red to orange pigments.
- They absorb strongly the **blue-violet range**.
- **Carotenoids and chlorophyll b** are called accessory pigments, since they absorb light and transfer the energy to chlorophyll a, which then initiate the light reaction.
- **Carotenoids → Chlorophyll 'b' → Chlorophyll 'a'**

Functions

- They broaden the spectrum of light that provides energy for photosynthesis.
- Some of these may **protect chlorophyll** by absorbing and dissipating intense light.
- Similarly, carotenoids may **protect human eye.**

ROLE OF WATER AND CO_2

Role of Water

Oxygen released during photosynthesis comes from water and is an important source of atmospheric oxygen, which most organisms need for ***aerobic respiration*** and thus for obtaining energy to live.

Discovery about Involvement of Water in Oxygen Production

- In 1930s, **Van Niel** hypothesized that plants split water as a source of hydrogen, releasing oxygen as a by-product. Neil's hypothesis was based on his investigations on photosynthesis in bacteria that make carbohydrate from carbon dioxide, but do not release oxygen.
- Neil's hypothesis was later confirmed by scientists during 1940s when first use of biological tracer (O^{18}) in biological research was made. Carbon dioxide and water containing heavy-oxygen isotopes O^{18} were prepared in the laboratory. Two groups of plants were made.

First Group

- Experimental green plants of first group were supplied with H_2O containing O^{18} and with CO_2 containing common oxygen O^{16}.
  These plants produced O^{18}.

$$\text{Group} - 1 \text{ plants: } CO_2 + 2H_2O^{18} \longrightarrow CH_2O + H_2O + {}^{18}O_2$$

Second Group

- Plants in the second group were supplied with H_2O containing common oxygen O^{16} but with CO_2 containing O^{18}.
  These plants did not produce O^{18}.

$$\text{Group 2 Plants: } CO^{18}{}_2 + 2H_2O \longrightarrow CH_2O^{18} + H_2O^{18} + O_2$$

- These experiments showed that oxygen produced during photosynthesis comes from water.

Role of CO_2

Source of CO_2

- Reduction of CO_2 is done during light-independent reactions of photosynthesis by using ATP and NADH (products of light-dependent reaction). Due to this, sugar is formed. This shows that photosynthesis is not possible in the absence of CO_2.
- About **10 percent** of total photosynthesis is carried out by terrestrial plants, and the rest occurs in oceans, lakes and ponds.
- Aquatic photosynthetic organisms use dissolved CO_2, bicarbonates and soluble carbonates that are present in water as carbon source.
- Photosynthesis occurring on land utilizes atmospheric CO_2. Air contains **0.03-0.04** percent of CO_2.

Passage of CO_2 to Enter in Plants

- Carbon dioxide enters the leaves through stomata and gets dissolved in the water absorbed by the cell walls of mesophyll cells. Stomata are found in a large number in a leaf. Their number is proportional to the amount of gas diffusing into the leaf. **Stomata** cover only **1-2%** of the leaf surface but they allow proportionally much more gas to diffuse.

Effect of Opening and Closing of Stomata

- The entry of CO_2 into the leaves depends upon the opening of stomata.
- Stoma is an opening surrounded by guard cells. Because of peculiar structure and changes in their shape, they regulate the opening and closing of stomata.
- Stomata are adjustable pores, which are;
- Open during daytime when CO_2 is required.
- Closed at night when photosynthesis stops.

POINT TO PONDER

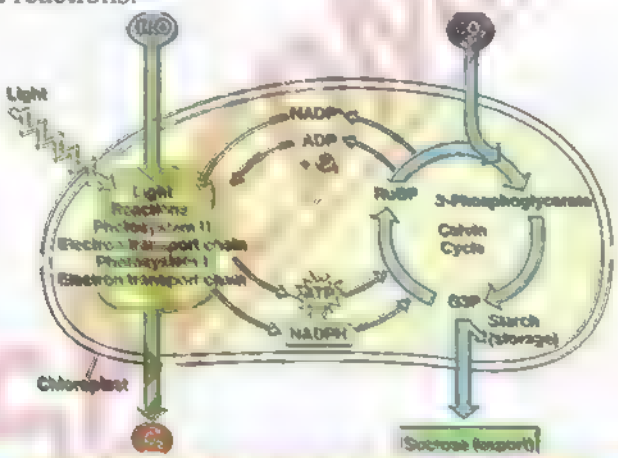
How will you explain that 'guard ce
multi-sensory hydraulic val

Reactions of Photosynthesis

- Photosynthesis is a 'redox process'.
- Overall equation of photosynthesis is:

$$6CO_2+12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

- These reactions of photosynthesis consist of two parts i e. light-dependent reactions and light-independent reactions.



LIGHT DEPENDENT REACTIONS

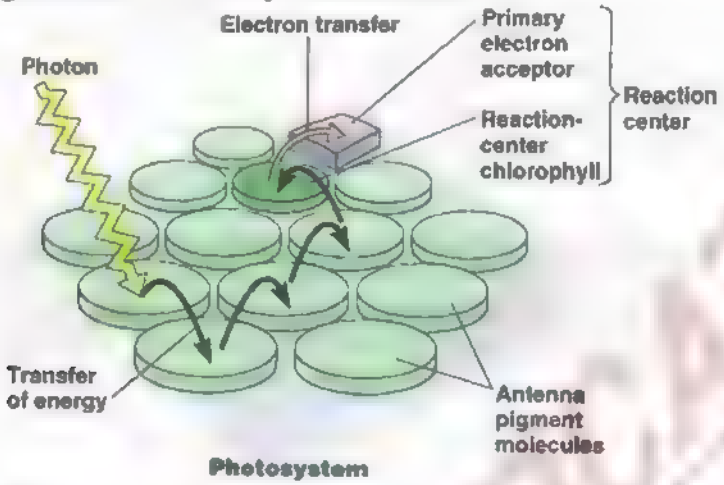
- Such types of reactions, which require light and constitute that phase of photosynthetic reaction during which light energy is absorbed by chlorophyll and other photosynthetic pigments and is converted into chemical energy, are called light reactions.
- As a result of this energy conversion, reducing and assimilating powers in the form of $NADPH_2$ ($NADPH + H^+$) and ATP are formed. Both temporarily store energy and carry along with H^+ to the light independent reactions.

Photosystems

- Photosynthetic pigments are organized into clusters called **photosystems**.
- Photosystem are meant for efficient absorption and utilization of solar energy and are **located on thylakoid membranes**.
- Each photosystem consists of two parts:

(i) **Antenna complex** has many chlorophyll 'a', 'b' and carotenoids, which channelize energy to reaction centre.

(ii) **Reaction centre** is constituted by chlorophyll 'a' along with primary electron acceptor and associated electron carriers of electron transport system. Electron transport system plays role in generation of ATP by chemiosmosis.



Types of Photosystem

- There are two photosystems; photosystem-I and photosystem-II. These are named so in order of their discovery.
- **PS I** have chlorophyll a molecule in reaction centre which absorbs maximum light of 700 nm, also called as P_{700}.
- **PS II** has a form of chlorophyll a molecule in reaction centre which absorbs maximum light of 680 nm, also called as P_{680}.

Non-Cyclic Photophosphorylation

Introduction

- It is predominant type of electron transport.
- Formation of ATP during non-cyclic electron flow is called non-cyclic photophosphorylation.
- Non-cyclic phosphorylation is also called **Z-scheme**, due to flow of electrons in Z-shape.

Mechanism

- Important steps of non-cyclic photophosphorylation are:

(i) Photo-excitation of electrons.
(ii) Photolysis of water.
(iii) Electron transport and formation of ATP through chemiosmosis.
(iv) Formation of $NADPH_2$.

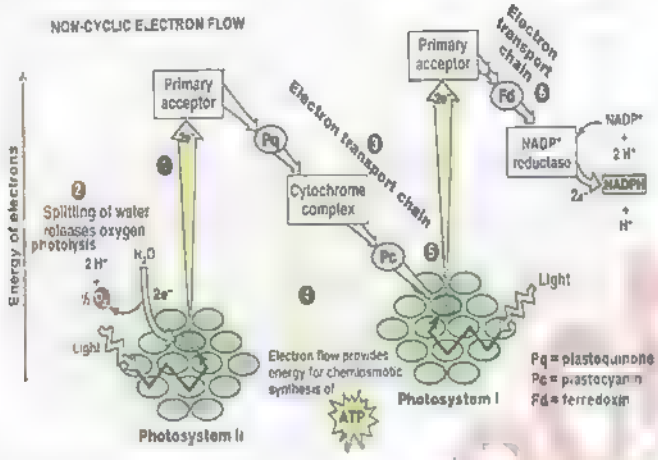
- The oxygen produced during photolysis is the main source of replenishment of atmospheric oxygen.
- Plastoquinone (Pq), Cytochromes and Ferredoxin (Fd) are iron containing electron carriers while Plastocyanin (Pc) is copper containing electron carrier.
- One photon excites one electron.

Passage of Electrons

PS II → PEA → Pq → Cytochrome Complex → Pc → PS I → PEA → Fd → $NADP^+$

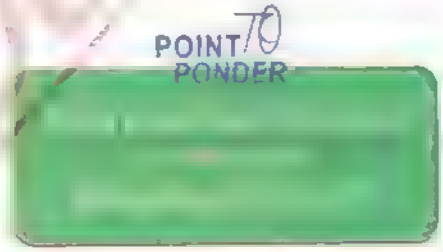
End Products of Light Reaction

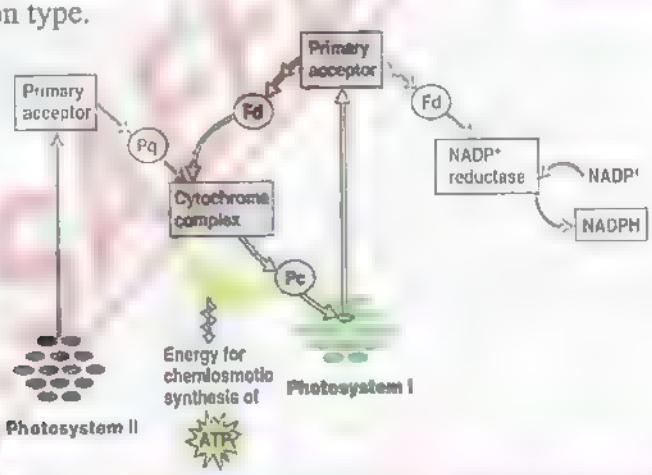
- NADPH/ $NADPH_2$
- ATP
- Molecular oxygen



Cyclic Photophosphorylation

- It occurs at that time when chloroplast run low on ATP for Calvin cycle, the cycle slows down and NADPH accumulate in chloroplast.
- This rise in NADPH may stimulate a temporary shift from non-cyclic to cyclic electron flow until ATP supply meets the demand.
- It is less common type.



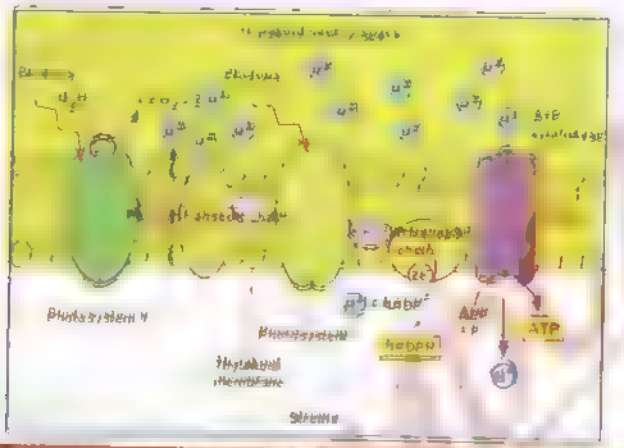


Comparison of Cyclic and Non-Cyclic Phosphorylation

Electrons are not reused.	Electrons are reused.
It involves both PS I and II.	It involves only PS I.
It is long pathway.	It is short circuit.
It is normal process.	It occurs when ATP is less and NADPH is more.
It generates both ATP and NADPH.	It generates only ATP.
H_2O splits.	H_2O does not split
Oxygen is released.	Oxygen is not released.

Chemiosmosis

- In both cyclic and non-cyclic photophosphorylation, the mechanism for ATP synthesis is chemiosmosis.
- It is the process that uses membranes to couple redox reactions to ATP production.
- Flow of Electrons through ETC → Release of Energy → Pumping of protons (H^+) across thylakoid membrane → Transformation into potential energy stored in form of H^+ gradient → Movement of H^+ down the gradient through ATP synthase → Formation of ATP



LIGHT INDEPENDENT REACTIONS

- Those reactions which do not require light directly and can occur in the presence or absence of light provided that assimilatory power in the form of ATP and reducing power $NADPH_2$, produced during the light reactions, is called dark reactions and constitute light independent phase of photosynthesis.

POINT TO PONDER

- $NADPH_2$ provides energized electron and H^+ while ATP provides chemical energy for the synthesis of sugar by reducing CO_2.
- These reactions take place in stroma of chloroplast.

POINT TO PONDER

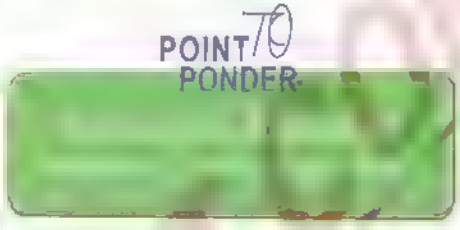
- The cyclic series of reactions, catalyzed by respective enzymes, by which the carbon is fixed and reduced, resulting in the synthesis of sugar during the dark reaction, is called **Calvin Cycle.**
- It is divided into three steps:

(i) Carbon fixation
(ii) Reduction
(iii) Regeneration of CO_2 acceptor.

CO_2 Fixation

- Carbon fixation refers to the initial incorporation of CO_2 into organic material.
- CO_2 fixation is dependent on ribulose bisphosphate carboxylase (**Rubisco**).

- Rubisco is most abundant protein in chloroplast and on earth.
- Three CO_2 molecules are required to synthesize one molecule of carbohydrate, a triose.
- First product is highly unstable 6-carbon compound that immediately breaks into two molecules of 3-carbon compound.



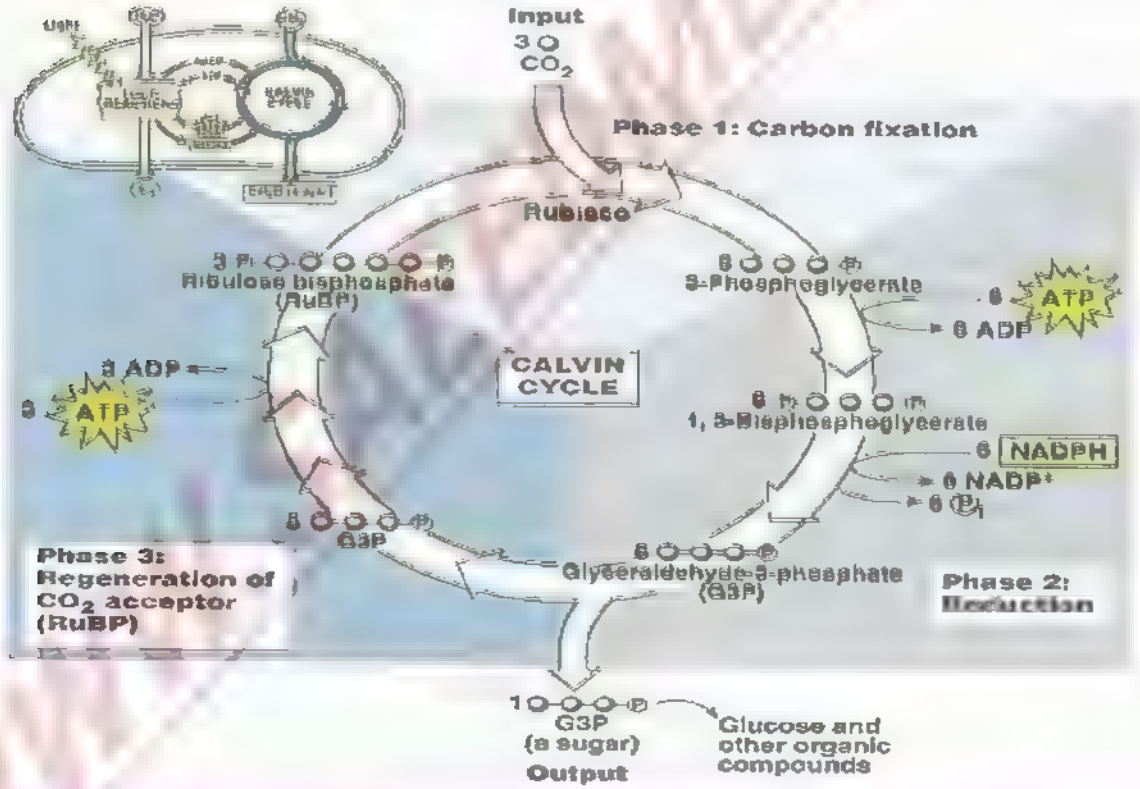
Reduction

- This reduction phase involves utilization of products of light reaction.
- Reduction of three molecules of CO_2 requires 6 ATP and 6 $NADPH_2$ molecules.
- G3P (product of Calvin cycle) is also obtained during this phase.

Regeneration of RuBP

- Five molecules of G3P are recycled into 3 molecules of RuBP.
- This conversion requires energy that is provided by ATP from light reactions.
- For regeneration of 3 molecules of RuBP, 3 ATP molecules are consumed.

$$3CO_2 + 6NADPHH^+ + 9ATP \rightarrow (CH_2O)_3 + 6NADP^+ + 9ADP + 9P_i + 3H_2O$$



Comparison of Light and Dark Reactions

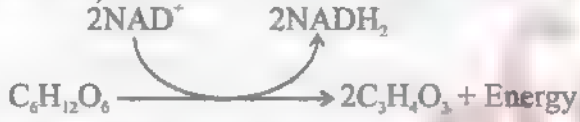
Light Reactions	Dark Reactions
Occur in grana of chloroplast.	Occur in stroma of chloroplast.
Light is required.	Light is not required.
O_2, ATP and $NADPH_2$ are the end products.	In Calvin cycle, ATP and $NADPH_2$ are used to prepare carbohydrates.
Water is used	CO_2 is used

CELLULAR RESPIRATION (SERIES OF CATABOLIC REACTIONS)

- Respiration is the universal process by which organisms breakdown complex compounds containing carbon in a way that allows the cells to harvest a maximum of usable energy.
- **External respiration** involves exchange of respiratory gases between the organism and its environment.
- **Cellular respiration** is the process by which energy is made available to cells in a step by step breakdown of C-chain molecules in the cell.
- Cellular respiration is **essentially an oxidation** process.
- The most common fuel used by the cell to provide energy by cellular respiration is glucose.

Aerobic and Anaerobic Respiration

- The way glucose is metabolized depends on the availability of oxygen.
- First step of cellular respiration (Glycolysis that splits glucose molecule into two molecules of pyruvic acid) is common in aerobic and anaerobic respiration.



- The next step in cellular respiration varies depending on the type of cell and prevailing conditions.
- Cell processes pyruvic acid in three major ways:

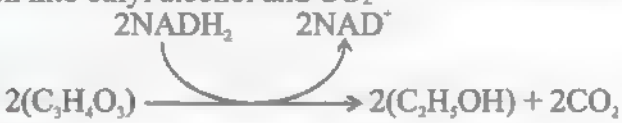
(i) Alcoholic fermentation
(ii) Lactic acid fermentation
(iii) Aerobic respiration

Feature	Aerobic Respiration	Anaerobic Respir.
Involvement of Oxygen	Occurs in presence of O_2	Occurs in absence of O_2
Reactants	Glucose & O_2	Glucose
Glucose Breakdown	Involves complete breakdown of glucose	Involves incomplete breakdown of glucose
End Products	CO_2, H_2O and energy	Lactic acid or Ethyl alcohol & CO_2
ATP Formed	Total: 40 ATP Net: 36 or 38 ATP	Total: 4 ATP Net: 2 ATP
Energy of Glucose Released	98%	2%
Location in Eukaryotic Cell	Mitochondria	Cytoplasm

ANAEROBIC RESPIRATION

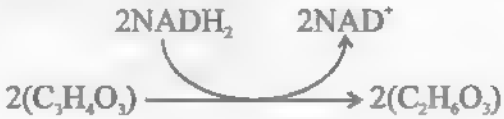
(i) Alcoholic Fermentation

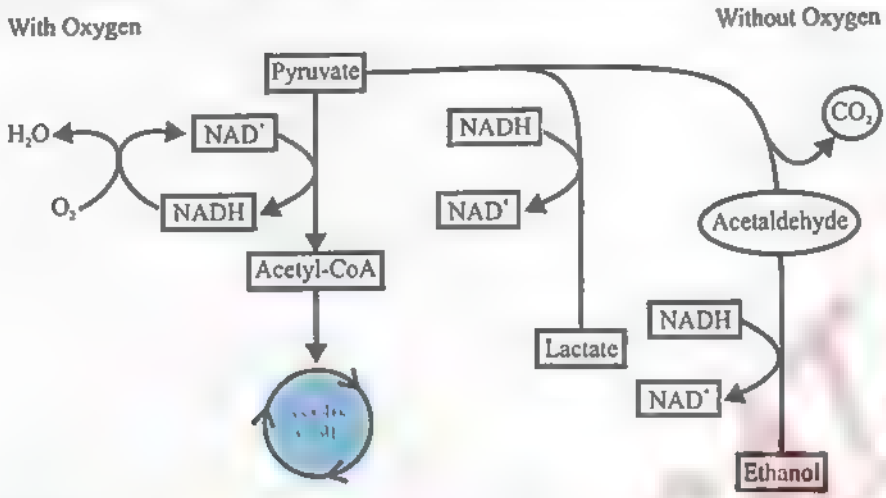
- It occurs in primitive cells and in some eukaryotic cells such as **yeast**.
- Pyruvic acid is broken into ethyl alcohol and CO_2



(ii) Lactic Acid Fermentation

- It occurs in muscle cells of humans and other animals during extreme physical activities such as sprinting.
- Pyruvic acid is metabolized in lactic acid.





Aerobic Respiration

Aerobic respiration may be subdivided into four stages:

(i) Glycolysis
(ii) Pyruvic acid oxidation
(iii) Krebs cycle or citric acid cycle or Tricarboxylic acid cycle
(iv) Respiratory chain.

- Glycolysis is the breakdown of glucose up to the formation of pyruvic acid.
- It occurs in **cytoplasm**.
- It takes place in the absence (**Anaerobic**) or in the presence of O_2 (**Aerobic** conditions).
- Enzymes, ATP, and Coenzyme NAD^+ are essential for glycolysis.

Phases of Glycolysis

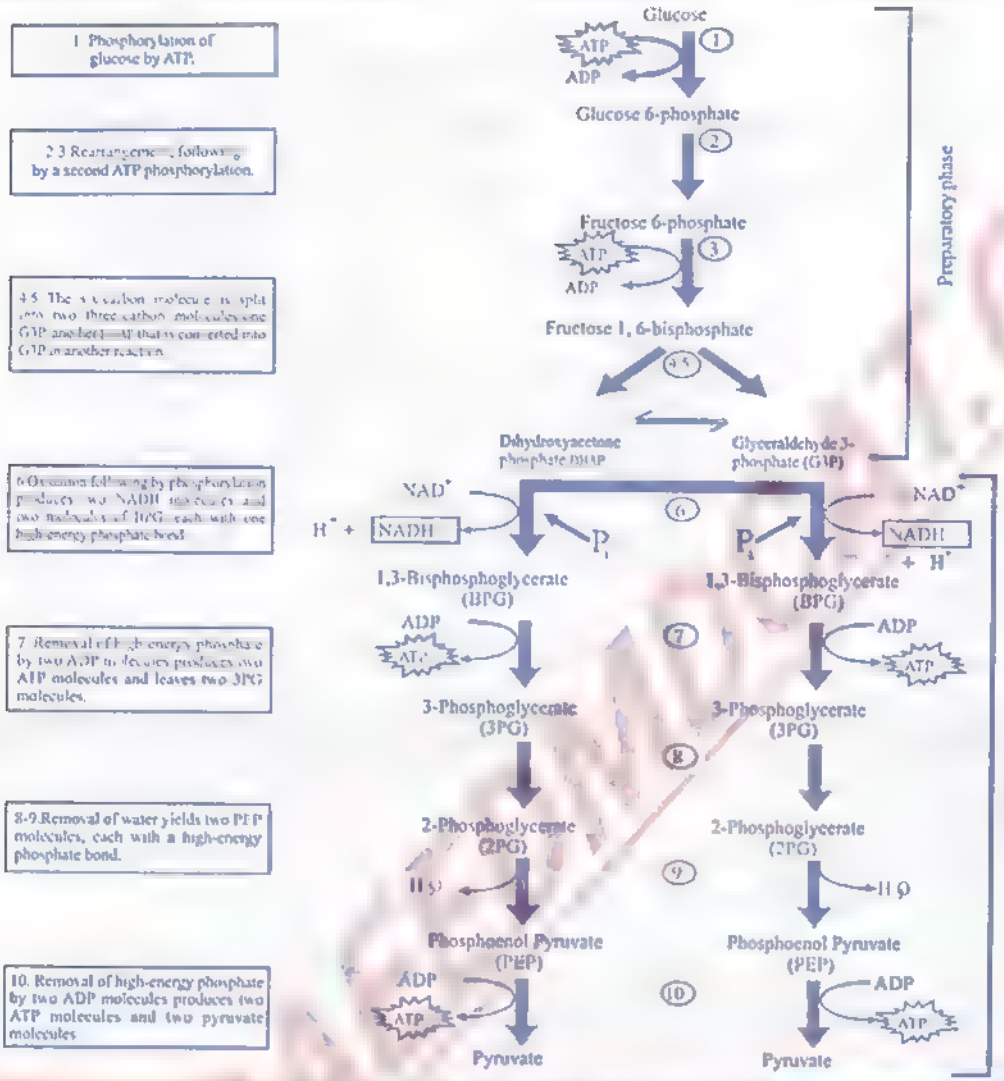
- There are **two phases** of glycolysis i.e. preparatory phase and oxidative phase
- **Preparatory phase** involves the conversion of glucose into one molecule of G3P and one molecule of DHAP. It utilizes two molecules of ATP.
- **Oxidative or pay off phase** involves conversion of G3P into pyruvate along with the formation of 4 ATP and 2 NADH molecules.

End Products

- Total consumption of ATP during glycolysis is 2ATP molecules
- Total production of ATP during glycolysis is 4ATP molecules.
- Net production of energy during glycolysis is 2ATP molecules.

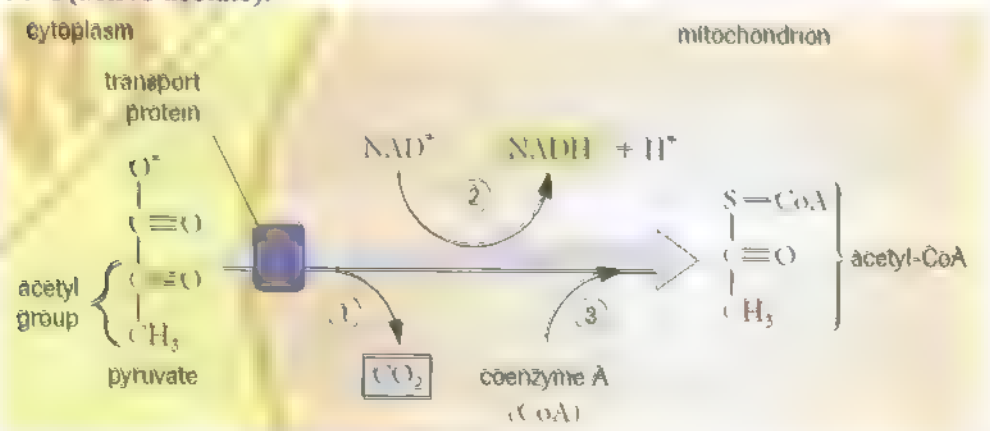
POINT TO PONDER

POINT TO PONDER



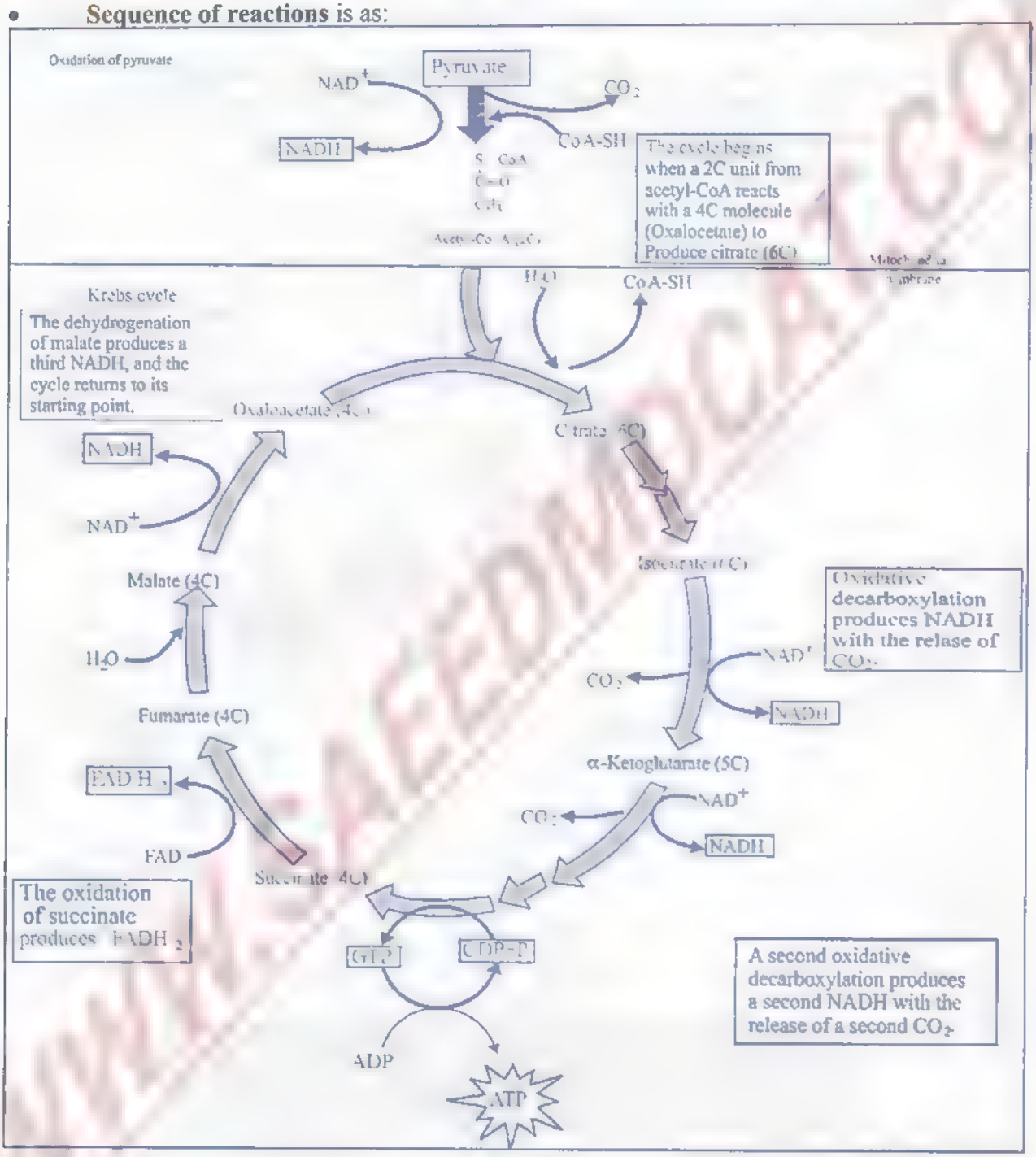
PYRUVIC ACID OXIDATION

- This is also called as **link reaction**.
- Pyruvic acid does not enter Krebs cycle directly. It is decarboxylated and oxidized into acetic acid (2C).
- Acetic acid on entering the mitochondrion unites with coenzyme-A (CoA) to form acetyl CoA (active acetate).



KREBS CYCLE

- It is also called **citric acid cycle** or tricarboxylic acid (TCA) cycle.
- **Sequence of reactions** is as:

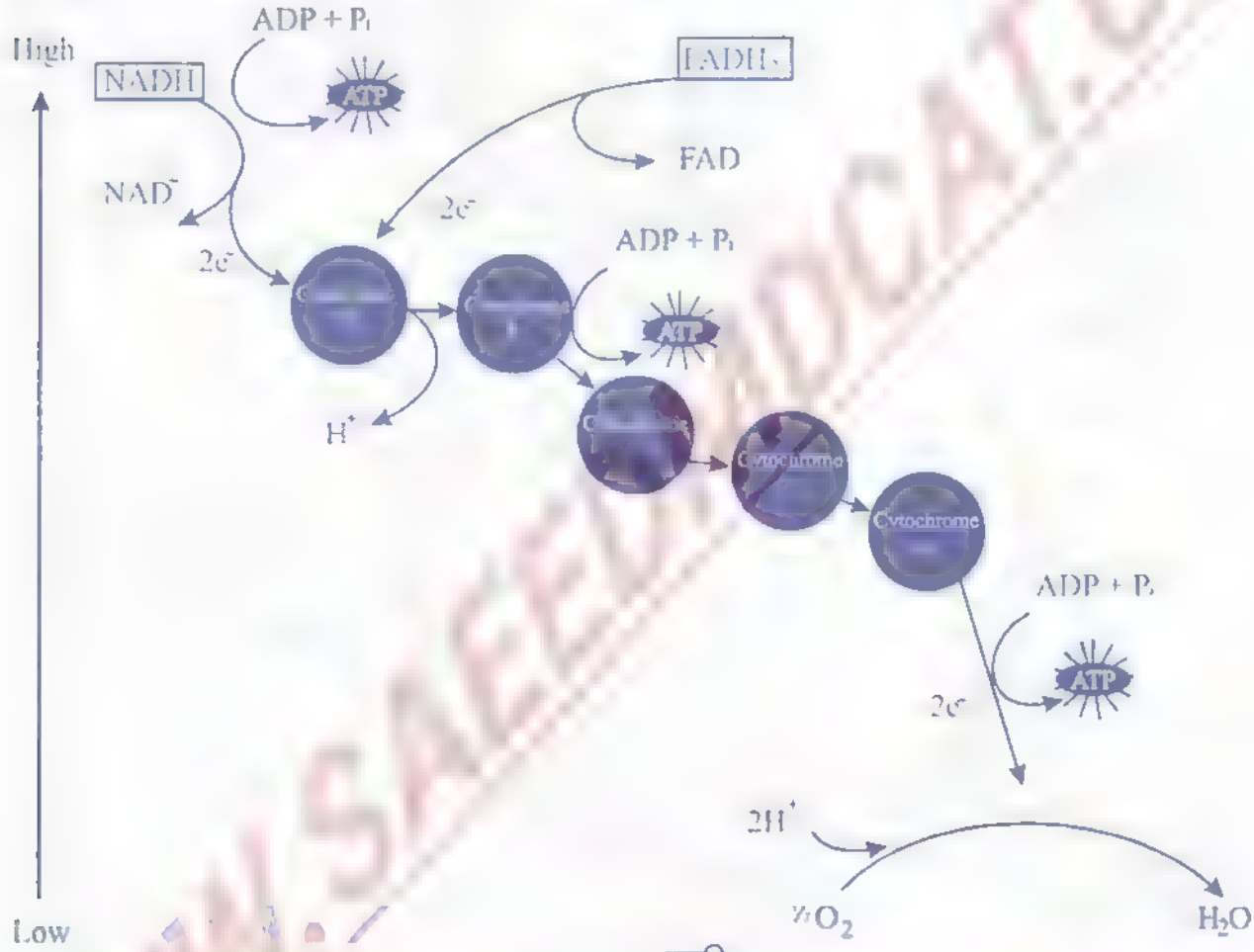


- One Krebs cycle yields one molecule of ATP, three molecules of NADH and one molecule of $FADH_2$.

POINT TO PONDER

OXIDATION THAT IS COUPLED TO PHOSPHORYLATION

- A system where electrons are transported in a series of oxidation-reduction steps to react ultimately, with molecular oxygen is called **electron transport system or respiratory chain**.
- Synthesis of ATP in the presence of O_2 is called **oxidative phosphorylation**.
- During **oxidative phosphorylation,** 3 ATPs are formed from one NADH and two ATPs are formed from one $FADH_2$.
- **Sequence of electron flow** is as follows:



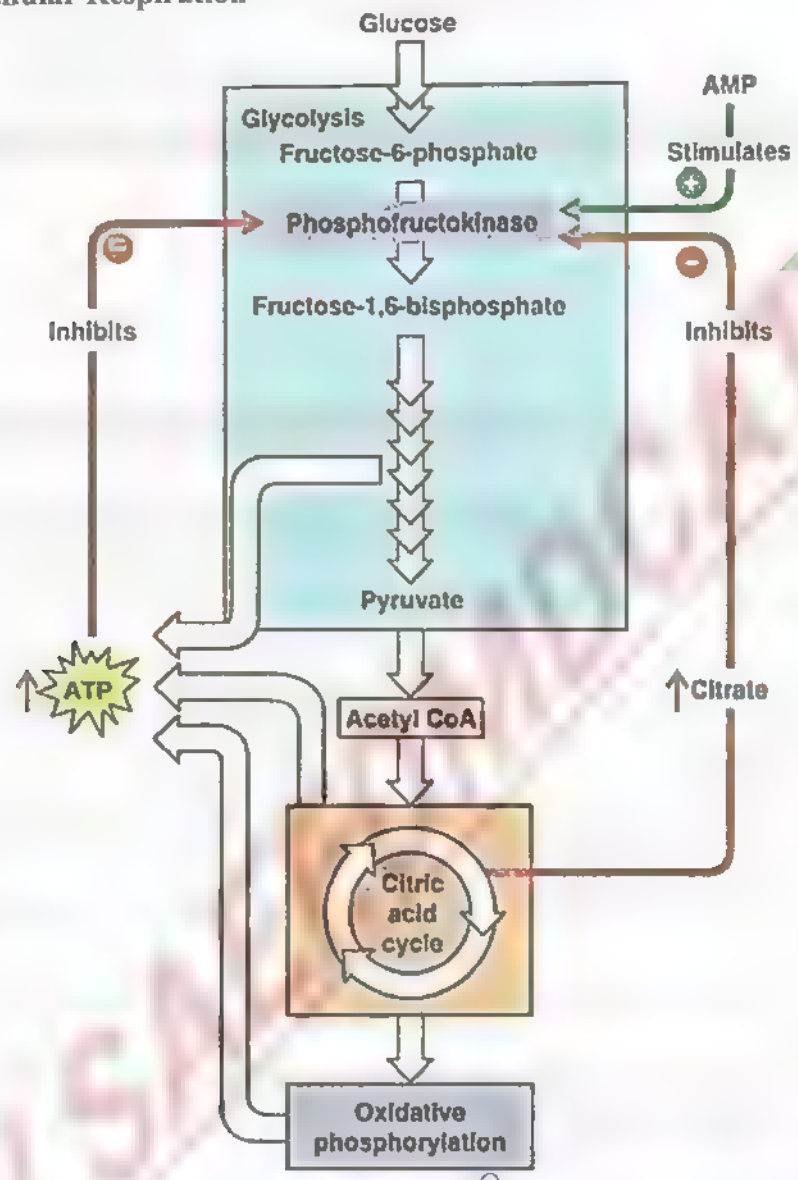
POINT TO PONDER

Is there any difference between number of ATPs produced by aerobic respiration of glucose in eukaryotes and prokaryotes?

Oxidative Phosphorylation

- Synthesis of ATP in the presence of oxygen is called oxidative phosphorylation.
- Oxidative phosphorylation is coupled with respiratory chain in the inner membrane of mitochondrion.
- As compared to photosynthesis, here pumping of protons (H^+) is across the inner membrane of mitochondrion folded into cristae, between matrix of mitochondrion and mitochondrion's inter-membrane space.

Regulation of Cellular Respiration



POINT TO PONDER

Can you elaborate the role of oxygen in aerobic respiration?

TOPIC-5 » ACELLULAR LIFE

COURSE CONTENT

- Discovery of Viruses
- Structure of Virus
- Classification of viruses
- Bacteriophages (Structure and Life Cycle)
- Viral Diseases
- HIV and AIDS

DISCOVERY OF VIRUSES

Discovery of Viruses

Edward Jenner	1796	1st vaccine against small pox (viral disease).
Charles Chamberland	1884	Filterable nature of rabies viruses.
Ivanowski	1892	Filterable nature of TMV
W. M. Stanley	1935	Isolation, purification and crystallization of TMV
Twort and D'Herelle	1915, 1917	Discovery of bacteriophages

Characteristics of Viruses

- Viruses are non-cellular infectious entities which contain either RNA or DNA genome, normally encased in proteinaceous coat. This suggested that, unlike other pathogens, viruses are of simple chemical composition.
- They reproduce only within the living cells and then transfer themselves efficiently to other cells.

Size

Viruses are extremely small infectious agents, which can **only be seen under an electron microscope.**

- They range in size from **250 nm** of **poxviruses** to the **20 nm** of **parvoviruses**.
- They are **10** to **1000 times smaller than most bacteria,** so they can pass through the pores of filter, from which bacteria cannot pass.

Obligate Parasites

- Viruses **cannot be grown on artificial media.** They can reproduce only in animal and plant cells or in microorganisms, where they reproduce by replication (a process by which many copies or replicas of virus are formed).
- Thus the viruses are said to be **obligate intracellular parasites.**

Nature

- Viruses **lack metabolic machinery** for the synthesis of their own nucleic acid and protein. They depend on the host cell to carry out these vital functions.
- During reproduction in the host cells, **viruses may cause disease.**
- All viruses are **generally resistance to broad range of available antibiotics** such as penicillin, streptomycin and others.
- **Prions** are infectious particles made only of proteins and cause mysterious brain infection in man and mad cow infection in cow.
- **Viroids** are minute particles of RNA and lack protein coat. They cause diseases in both plants and animals.

STRUCTURE OF VIRUS

- A complete, mature and infectious particle is known as **virion.**
- Primarily, it can be divided into two parts i.e. **core and coat.**

Central Core

- The core is inner part of virion which consists of viral genome and various proteins (enzymes).
- Genome is the genetic material which is **either DNA or RNA** and may be single stranded or double stranded.

Outer Coat

- The coat is the outer covering of viral particle which consists of capsid and envelope.
- **Capsid** is made up of protein subunits known as **capsomeres.** The number of capsomeres is specific to a particular kind of virus.
- 162 capsomeres are present in capsid of herpes virus and 252 in the capsid of adenovirus.
- There are two forms of symmetry in virus capsid i.e. **cubical or helical**. When the capsomeres are arranged in 20 triangles, it is called icosahedral (polyhedral or spherical). When the capsomeres are arranged in a hollow coil that appears rod shaped, it is called helical.
- A few viruses have an additional **lipoprotein envelope** around the capsid which is derived from the cell surface membrane of the host and also contain virally encoded proteins. Non-enveloped viruses are known as **naked viruses.**

CLASSIFICATION OF VIRUSES

Virus classification is generally based upon;

(i) Host
(ii) Morphology
(iii) Genome
(iv) Mode of action
(v) Mode of replication

The internationally agreed system of virus classification is based on the structure and composition of the virus particle (virion).

Classification of Viruses Based Upon Host

Viruses can be classified on the basis of their host e.g.

A. Bacteriophages
B. Plant viruses
C. Animal viruses

A. Bacteriophage Virus

It attacks bacteria. It is a **DNA** virus with a polyhedral head and a tail.

B. Plant Viruses

More than 2,000 types of viral plant diseases are known.

Examples

- Most plant viruses discovered till to date including tobacco mosaic virus (TMV), having an **RNA genome.**
- Many viruses have rod shaped capsid like TMV, potato yellow dwarf virus.

C. Animal viruses

Animal viruses occur as parasites in animals. In many viral infections viruses attack and destroy certain cells in the human body causing the symptoms and diseases.

Examples

- Viruses cause foot and mouth disease in livestock.
- *Rous sarcoma* virus causes cancer in animals. Parvovirus causes warts.
- Poxvirus causes small pox.
- Picornavirus causes polio, hepatitis A etc.
- Paramyxovirus causes measles and mumps.

Classification of Viruses Based Upon Structure

(i) **On The Bases of Capsid**

Although diverse in size and shape, viruses have common features, most of which appear in the following four types;

(a) **Polyhedral capsid**

Viruses having a polyhedral capsid with overall shape of a rigid rod e.g. tobacco mosaic virus

(b) **Helical a polyhedral capsid**

Viruses having helical a polyhedral capsid with a glycoprotein spikes at each vertex e.g. Adenoviruses.

(c) **Envelope**

Viruses having an outer envelope studded with glycoprotein spikes e.g. Influenza Viruses

(d) **Complex capsid**

Viruses having a complex capsid consisting of a polyhedral head and a tail apparatus, e.g. Bacteriophage.

(ii) **On The Bases of Genomes**

The genomes of viruses may consist of;

- **Double-stranded (dsDNA)**
  E.g. Poxvirus (smallpox virus, cowpox virus)
- **Single-stranded DNA (ssDNA)**
  E.g. Parvovirus (mild rash).
- **Double-stranded RNA (dsRNA)**
  E.g. Reovirus (diarrhea).
- **Single-stranded RNA (ssRNA)**
  Serves as mRNA e.g. Togavirus (Rubella virus)
- **ssRNA**
  Template for mRNA synthesis e.g. Orthomyxovirus (influenza virus)
- **ssRNA**
  ssRNA act as template for DNA synthesis e.g. Retrovirus (HIV)

BACTERIOPHAGES (STRUCTURE AND LIFE CYCLE)

The word "**bacteriophage**" literally means 'eater of bacteria', because they destroy their host cells. So, a bacteriophage is a type of virus that infects bacteria.

Life Cycle of Bacteriophage

So far the best studied phage virus is that which infect *E. coli* and is called T phage (T for type), and among them T_2 and T_4 phages mainly used in phage studies.

Structure of T_4

- T_4 resembles a **tadpole**, with a head and a tail.

- Its **head** is an elongated pyramidal, hexagonal, icosahedral, prism shaped structure, containing double stranded DNA and to which straight tail is attached.
- **Phage Tail** is hollow and more complex than head, consisting of an inner proteinaceous core, enclosed in a contractile sheath, made of another protein, to one end of which there is neck or **collar** and to the other **end plate**. **Six tail fibers** are attached with the end/ base plate. Tail fibers are involved in the binding of the phage to the bacterial cell.
- Phage volume is **1/1000** of its host i.e. *E. coli*.

Steps of Life Cycle

Bacteriophage replicates only inside the bacterial cell.

(i) Attachment/ Adsorption

First step is the attachment (adsorption) to the host cell at receptor site on the cell wall of bacterium. During attachment, weak chemical union between virion and receptor site takes place.

(ii) Penetration

Next step is penetration; the tail releases the enzyme lysozyme to dissolve a portion of bacterial **cell wall.** The tail sheath contracts and tail core is forced into the cell through cell wall and cell membrane.

(iii) Injection

Third step is injection of viral DNA in bacterial cell. The proteins coat, which forms the phage head and tail structure of virus remains outside the cell.

(iv) Replication Process

Two types of cycles are usually seen i.e. lytic and lysogenic cycle.

Lytic Cycle

(i) Viral DNA takes control of the host's biosynthetic machinery.

(ii) It induces the host cell to synthesize necessary viral components (DNA & Proteins) and start multiplying.

(iii) About 25 minutes after initial infection, approximately 200 new bacteriophages are formed.

(iv) Bacterial cell bursts i.e. it undergoes lysis.

(v) Newly formed phages are released to infect the bacteria and another cycle begins.

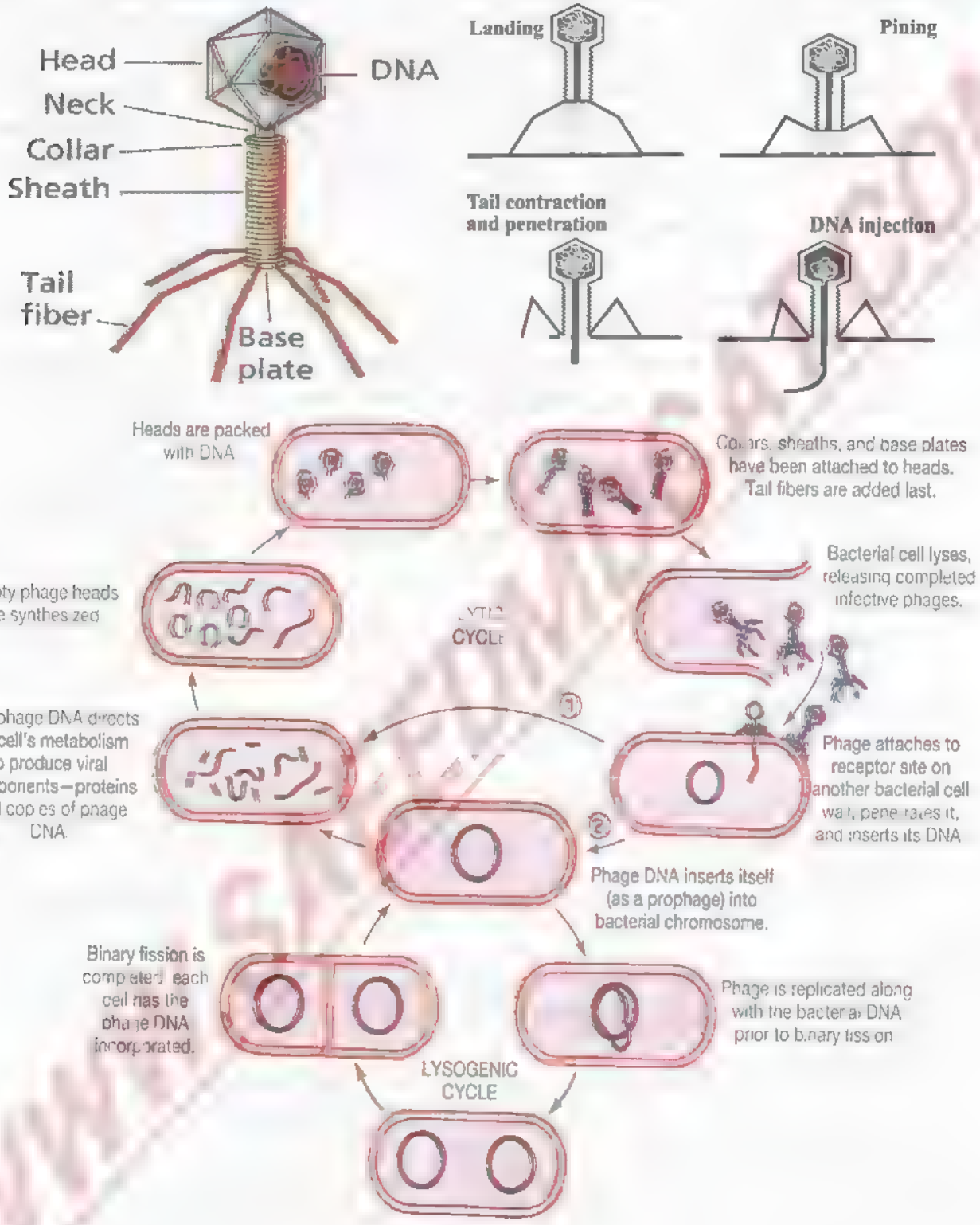
Lysogenic Cycle

(i) Viral DNA, instead of taking over the control of host's machinery, becomes incorporated into the bacterial chromosome. Phage in this dormant state is called prophage and this process is called lysogeny.

(ii) Bacterium continues to live and reproduce normally. Viral DNA being the part of bacterial chromosome passes to each daughter cell in all successive generations.

(iii) Sometimes viral DNA gets detached from the host's chromosome and lytic cycle starts. This process is called induction.

(iv) Induction involves either a **spontaneous or environmentally induced**. This results in the initiation of a typical lytic cycle, which ends in the lysis of the bacteria.


Head
Neck
Collar
Sheath
Tail fiber
Base plate
DNA
Landing
Pining
Tail contraction and penetration
DNA injection
Heads are packed with DNA
Collars, sheaths, and base plates have been attached to heads. Tail fibers are added last.
Bacterial cell lyses, releasing completed infective phages.
Empty phage heads are synthesized
The phage DNA directs the cell's metabolism to produce viral components—proteins and copies of phage DNA
Phage attaches to receptor site on another bacterial cell wall, penetrates it, and inserts its DNA
Phage DNA inserts itself (as a prophage) into bacterial chromosome.
Binary fission is completed; each cell has the phage DNA incorporated.
Phage is replicated along with the bacterial DNA prior to binary fission
LYSOGENIC CYCLE

Feature	Lytic Cycle	Lysogenic Cycle
Virus	Lytic or virulent phage	Lysogenic or temperate phage
Bacterium	Non-resistant	Resistant
Relationship	Master - Slave relation	Host - Guest relation
Effects	Infectious cycle	Non-infectious cycle
Viral DNA	Takes Control	Integrated
Bacterial DNA	Destroyed	Remains intact

VIRAL DISEASES

Disease	Virus	Source of Transmission	Symptoms	Immunization
Herpes Simplex (Oral herpes)	Herpes simplex type 1 virus (DNA enveloped virus)	Oral secretions or physical contact with sores or by objects (Toothbrush, utensils)	Blisters/ Vascular lesions in epithelial layers of ectodermal tissue. Most commonly in mouth, lips, and skin sites.	Antiviral drugs/ Avoid contact
Measles	RNA enveloped virus (Paramyxovirus)	Coughing & Sneezing	Fever, runny nose, cough. red eyes, red flat rashes on skin	Auto-immunity, Vaccination
Mumps	RNA enveloped virus (Paramyxovirus)	Coughing & sneezing	Fever, muscle pain, headache, painful swelling of parotid glands	Auto-immunity, Vaccination
Poliomyelitis	Polio virus/ Enterovirus (RNA non-enveloped virus, in spherical capsid). Smallest known virus	Oro-fecal route	Damage to motor neurons of spinal cord & leading to paralysis of limbs	Vaccination / Physiotherapy
Hepatitis A (Infectious)	Picornavirus (RNA non-enveloped virus)	Oro-fecal route	Acute infection (Nausea, vomiting, diarrhea, jaundice)	Vaccination/ Good hygiene
Hepatitis B (Serum)	Hepadnavirus (DNA enveloped virus)	Blood, Sexual contact, Mother to newborn	Acute (vomiting, yellowish skin, tiredness, dark urine, abdominal pain) & chronic (No symptoms, liver cirrhosis & liver cancer)	Vaccination/ Alpha interferons/ Screening of blood

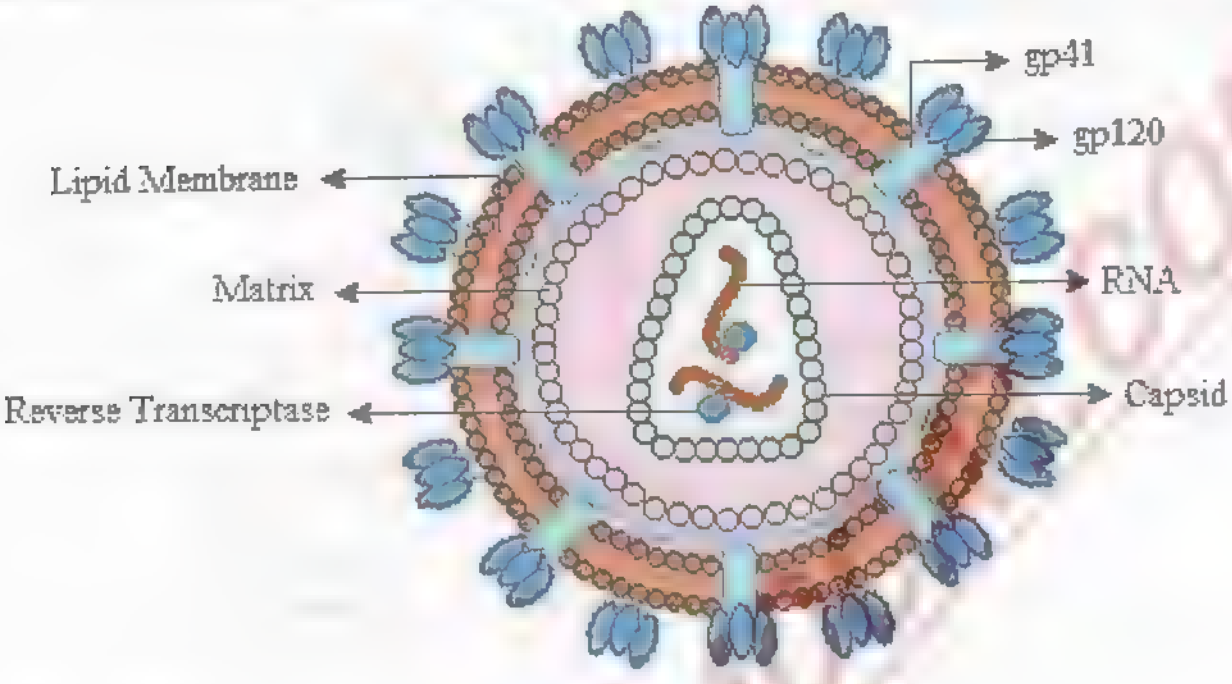
Hepatitis C (Infusion)	Flavivirus (RNA enveloped virus)	Blood	Chronic (ocassionally fever, dark urine, abdominal pain, yellow skin) with cirrhosis & liver cancer.	No Vaccination/ Alpha interferon & Ribavirin/ Screening of blood
Hepatitis D	Viroid	Blood or serum	Same as hepatitis B	Same as hepatitis B
Hepatitis E	RNA non-enveloped virus	Oro-fecal route	Acute infection (Nausea, vomiting, diarrhea, jaundice)	Good hygiene
AIDS	RNA enveloped virus	Blood/ Sexual contact	Opportunistic infections, Swollen lymph nodes	Vaccination NOT available

HIV AND AIDS

- Retroviruses are associated with tumor production in animals like fowl, rodents and cats.
- They are **spherical**, **100nm** in diameter, **enveloped** by host plasma membrane, and contain single stranded RNA as genome.
- Human immunodeficiency virus **(HIV)** which causes acquired immunodeficiency syndrome (AIDS) is a retrovirus.
- May be **non- specific** in their action but usually infect those cells containing **specific receptors**.
- **Reverse transcriptase** is a special enzyme which can convert **single stranded RNA genome into double stranded viral DNA,** which not only infect the host cell but also incorporate into host genome as a provirus that can pass on to progeny cells. In this way normal cells become cancer cells.

Human Immunodeficiency Virus (HIV)

- It is an RNA enveloped virus.
- HIV is spherical with conical capsid.
- The outer covering is a lipoprotein envelope.
- The viral core contains two single strands of RNA and enzymes needed for HIV replication, such as reverse transcriptase.
- Reverse transcriptase is used to convert viral RNA genome into viral DNA genome.



Host Specificity

- Primary hosts of HIV are **helper-lymphocytes** (CD4 cells).
- In addition, macrophages and certain brain cells may also be affected.

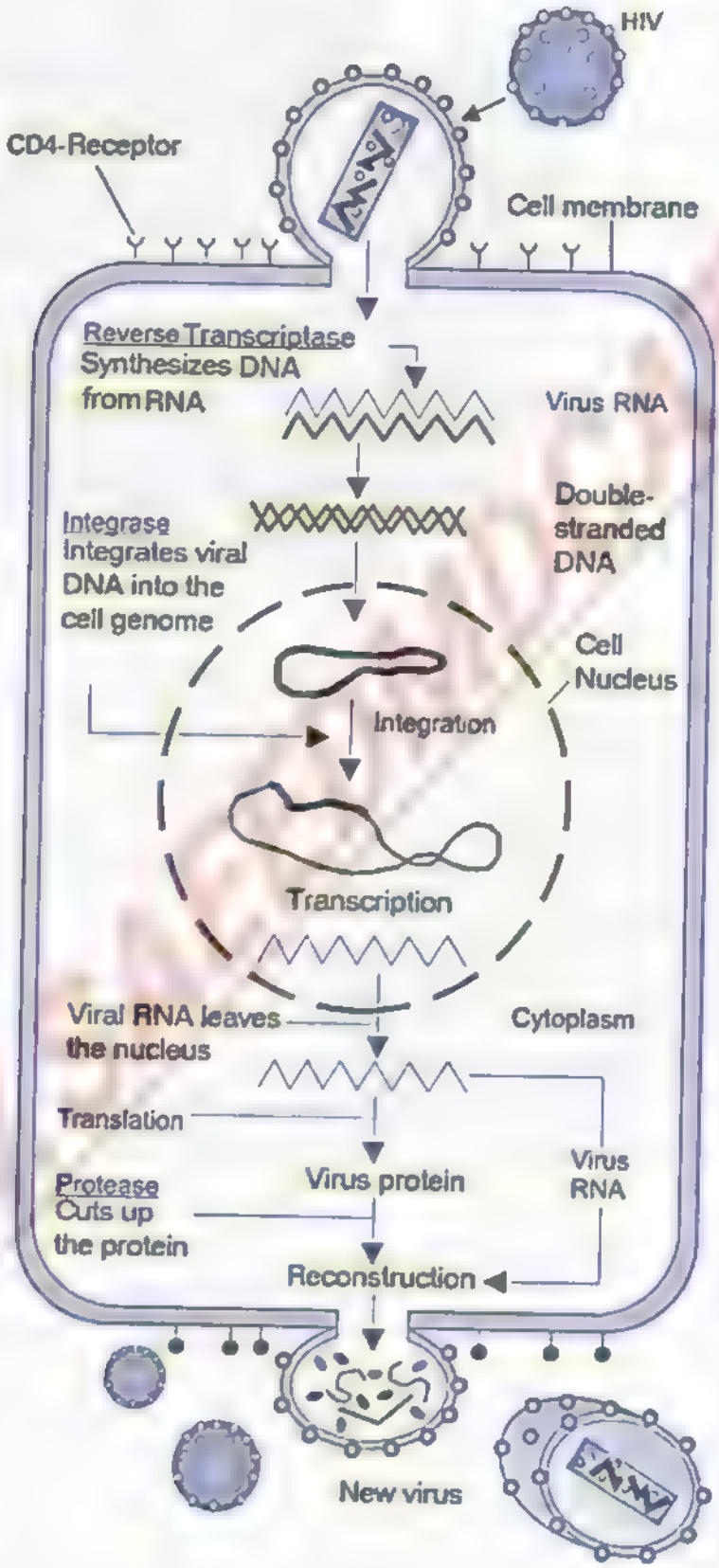
Mode of Transmission

- By intimate **sexual contact** (virus present in body secretions and blood, which gets entry in recipient blood from minor wear and tears, more common in homosexuals).
- Contact with blood and breast feeding.
- **Prick** of an infected needle or surgical instruments (problem for health care providers).

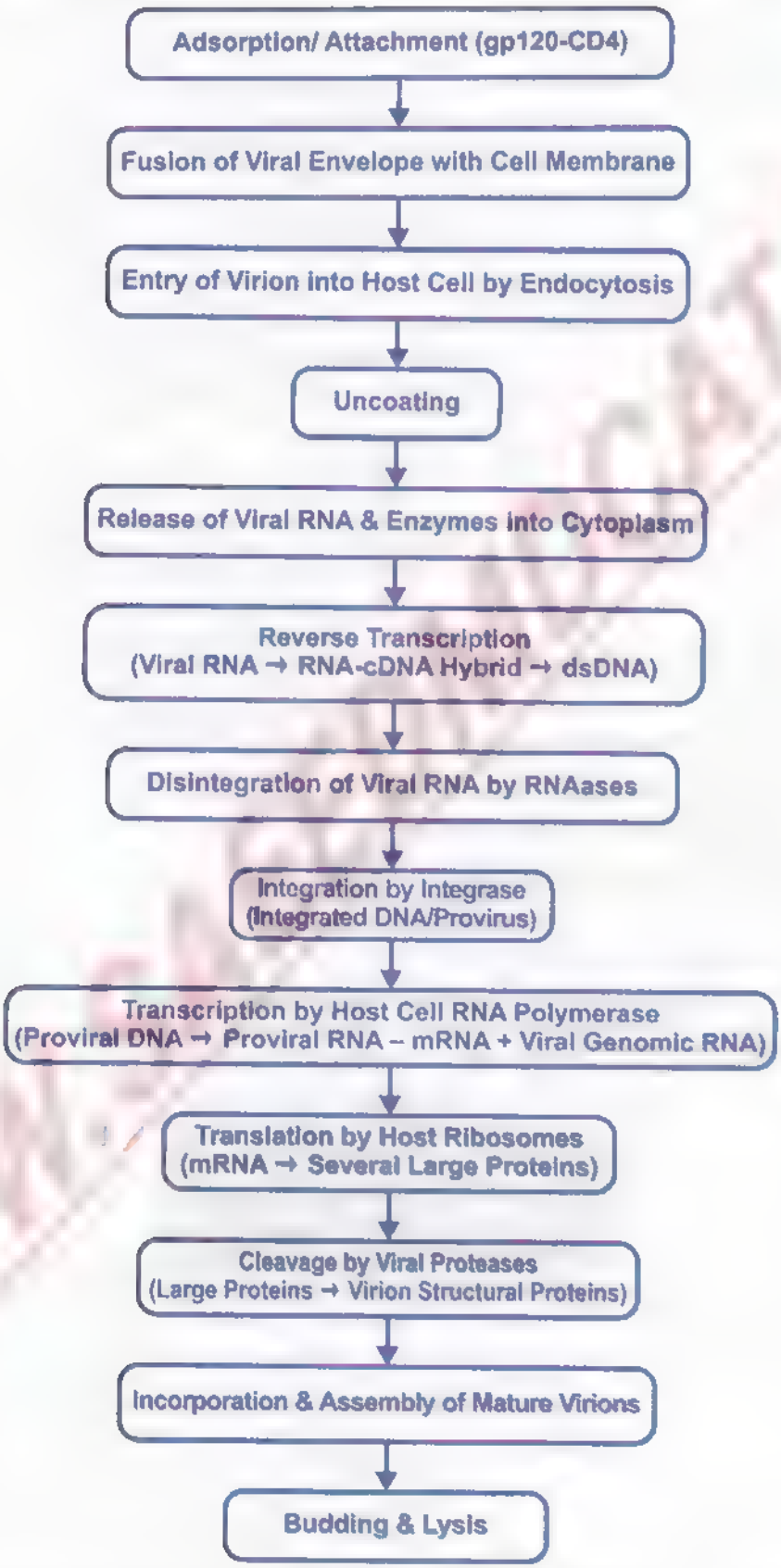
Acquired Immunodeficiency Syndrome (AIDS)

Acquired immunodeficiency syndrome (AIDS) first reported in **young homosexual males**, having one or more complex symptoms like severe pneumonia, vascular cancer, sudden weight loss, swollen lymph nodes and immune deficiency or decreased immune functions.

Life Cycle/ Infectious Cycle of HIV



Flow Chart


Adsorption/ Attachment (gp120-CD4)
Fusion of Viral Envelope with Cell Membrane
Entry of Virion into Host Cell by Endocytosis
Uncoating
Release of Viral RNA & Enzymes into Cytoplasm
Reverse Transcription
(Viral RNA → RNA-cDNA Hybrid → dsDNA)
Disintegration of Viral RNA by RNAases
Integration by Integrase
(Integrated DNA/Provirus)
Transcription by Host Cell RNA Polymerase
(Proviral DNA → Proviral RNA – mRNA + Viral Genomic RNA)
Translation by Host Ribosomes
(mRNA → Several Large Proteins)
Cleavage by Viral Proteases
(Large Proteins → Virion Structural Proteins)
Incorporation & Assembly of Mature Virions
Budding & Lysis

Symptoms of AIDS

An HIV infection can be divided into 3 stages:

(i) Asymptomatic Carrier

- Fever, chills, aches (continued pain), swollen lymph glands and itchy rashes.
- These symptoms disappear and there are no symptoms for 9 months or longer.
- The standard HIV blood test for the presence of antibody becomes positive during this stage.

(ii) AIDS Related Complex (ARC)

- Swollen lymph glands in neck, armpit or groin that persist for months. Other symptoms include night sweats, persistent cough, flu, persistent diarrhea, loss of memory, inability to think clearly, loss of judgment and depression.

(iii) Full Blown AIDS

- It is the final stage. In this stage, there is severe weight loss and weakness due to persistent diarrhea and usually one of the several opportunistic infections i.e. Kaposi's sarcoma (cancer or lesion on skin), fungal infection, viral infection, gastrointestinal disease, respiratory disease, nervous system and eye diseases).

Treatment of AIDS

Antiretroviral therapy (ART) is done for treatment. It is not a cure but it controls virus and increases life span of infected people.

Control Measures Against HIV Transmission

- Avoid sharing syringes, toothbrushes, towel and blades.
- Use of sterile needles, syringes and surgical instruments.
- Avoid prohibited sexual contacts.
- Screening of blood and blood products before transfusion.

TOPIC-6 » PROKARYOTES

COURSE CONTENT

- Bacteria (Size and Shape)
- Bacterial Cell Structure
- Nutrition in Bacteria
- Respiration in Bacteria
- Reproduction in Bacteria
- Importance and Control of Bacteria
- Cyanobacteria

BACTERIA (SIZE AND SHAPE)

- **Bacteria** are microscopic, single-celled organisms that thrive in diverse environments.

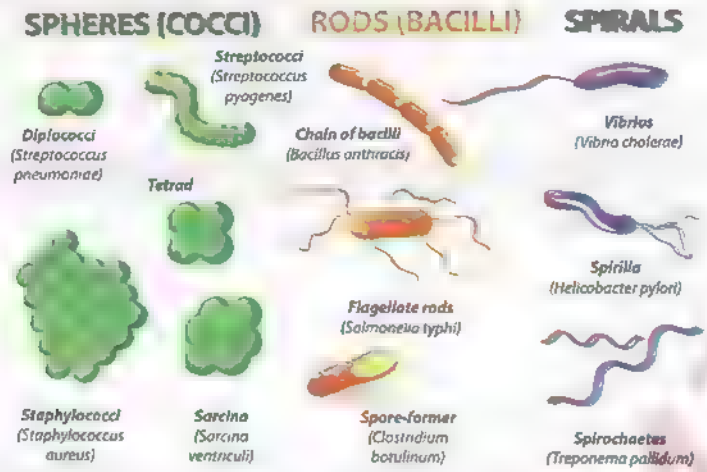
Size of Bacteria

Type	Size
Range	0.1-600 µm
Mycoplasma (Smallest)	100-200 nm
Escherichia coli	1.1-1.5 µm (width), 2.0-6.0 µm (length)
Spirochete	500 µm in length
Staphylococci & Streptococci	0.75-1.25 µm in diameter
Epulopiscium fishelsoni	600 µm x 80 µm

Shapes of Bacteria

- Bacteria may be **Cocci** (Spherical or oval in shape), **Bacilli** (Rod shaped) and **Spiral** (Curved/ spring shaped).
- Some have characteristic shapes, others are ***pleomorphic*** (variable shape).

Type	Arrangement	Division
Coccus	Spherical	No
Diplococcus	Two cocci	Single plane of division
Streptococcus	Cocci in chain	Single plane of division
Staphylococcus	Irregular arrangement	Random planes
Tetrad	Group of four	Two planes of division
Sarcina	Group of eight	Three planes of division
Bacillus	Rod shaped	No
Diplobacillus	Two bacilli	Single plane of division
Streptobacillus	Chain of bacilli	Single plane of division
Coccobacilli	Rod shaped with spherical ends	No
Spirals	Spirally coiled	No
Vibrio	Comma shaped	No
Spirillum	Thick, rigid spiral	No
Spirochete	Thin, flexible spiral	No

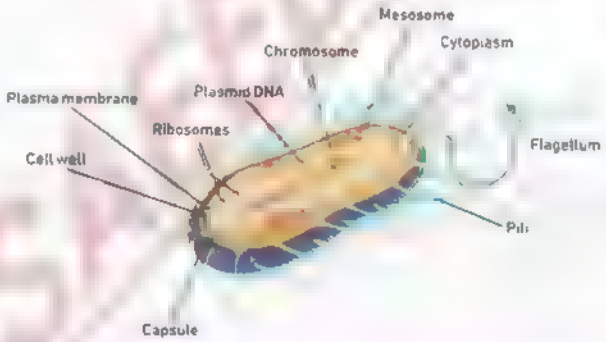


Some Important Examples

Cocci	*Diplococcus pneumoniae, Staphylococcus aureus, Neisseria meningitidis*
Bacilli	*Escherichia coli, Bacillus subtilis, Pseudomonas*
Spirals	*Vibrio cholera, Hyphomicrobium, Treponema pallidum, Spirrilum minus*

BACTERIAL CELL STRUCTURE

- All bacterial cells invariably have a cell membrane, cytoplasm, ribosomes and chromatin bodies.
- The majority have **cell wall**, which gives shape to the bacterial cell.
- **Specific structures** like capsule, slime, flagella, pili, fimbriae and granules are not found in all bacteria.

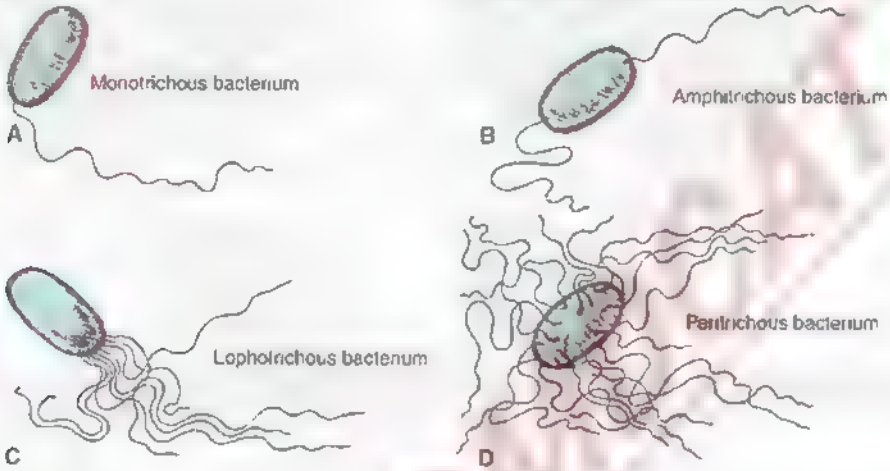


Flagella and Pili

Flagella	Pili / Fimbriae
Thin	Thick
Long	Short
Flexible, Helical	Rigid, Non-helical, Hollow
Originate from basal bodies, attached with plasma membrane & pass out through cell wall.	Originate from basal bodies, attached with plasma membrane & pass out through cell wall.
Made of flagellin protein	Made of pilin protein
Present in all except cocci. Cocci rarely have flagella.	Present in Gram negative bacteria while absent in Gram positive bacteria.
Help in locomotion/ motility/ chemotaxis.	Involved in attachment with host or with other bacterium for conjugation (Sex/F pili)

Classification on Base of Flagella

Type	Flagella
Atrichous	No flagella
Monotrichous	Single flagellum at one end
Amphitrichous	Single flagellum at both ends
Lophotrichous	Tuft of flagella at one pole
Peritrichous	Bacterium equally surrounded by flagella



Cell Envelope

- Complexes of layers external to the cell protoplasm are collectively called cell envelope and commonly include capsule, slime and cell wall.
- Capsule and slime form glycocalyx.

Capsule

- A **thick, gummy** structure giving sticky character to colonies of encapsulated bacteria.
- It is made up of **polysaccharide** units or **proteins** or both.
- It is tightly bound to the cell.

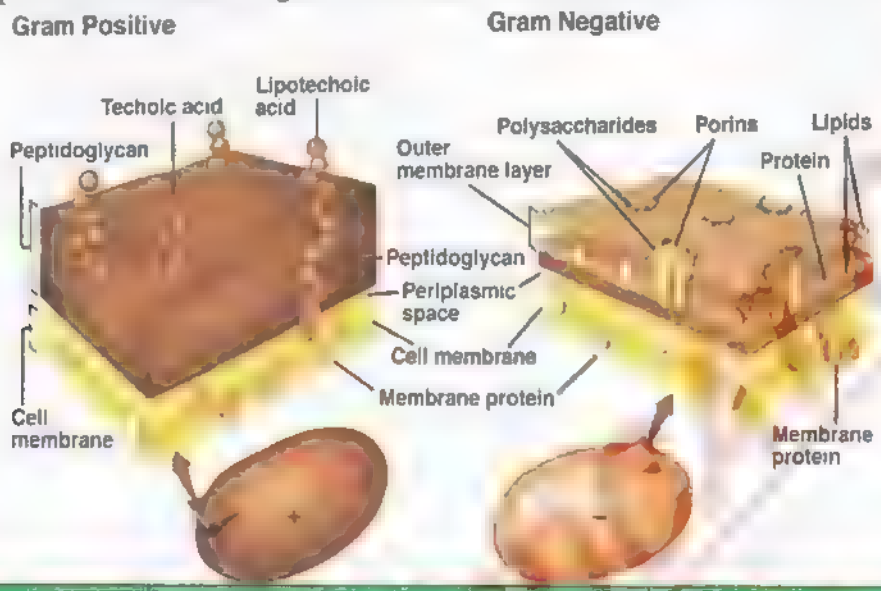
Slime

- **Loose soluble** shield of macromolecules outside capsule is called slime capsule.
- It can be removed from cell easily.
- Slime provides greater **pathogenicity** to bacteria.
- It protects them from **phagocytosis**.

Cell Wall

- A rigid structure between extracellular substances and cytoplasmic membrane.
- Cell wall is only **absent in Mycoplasma**.
- It is composed of a macromolecule called **peptidoglycan** consisting of long glycan chains cross linked with peptide fragments.
- **Sugar, teichoic acid, lipoproteins and lipopolysaccharides** are also present which are linked with peptidoglycan.
- Teichoic acid fibers protrude outside the peptidoglycan.
- Cell wall of archaebacteria does not contain peptidoglycan; rather contain proteins, glycoproteins and polysaccharides.
- It determines the **shape of bacteria**.
- It **protects** the cell from **osmotic lysis**.

- It provides **identity to different bacteria**, depending upon their staining characteristics i.e., Gram positive and Gram negative bacteria.



Stain	Primary dye (Crystal violet & Gram's iodine)	Secondary dye (Safranin)
Staining character	Purple	Pink
Number of major layers	1	2
Peptidoglycan	50% of dry weight	10% of dry weight
Lipids	1-4%	11-12%
Additional substances	Teichoic acid and lipoteichoic acid	Lipopolysaccharides, lipoproteins
Overall thickness	Thick 20-80 nm	Thin 8-11 nm
Outer membrane	No	Yes
Periplasmic space	Present in some	Present in all
Permeability	More permeable	Less permeable
Resistance	More	Less

- Periplasmic space lies between peptidoglycan layer of cell wall and cytoplasmic membrane. It is the site having certain enzymes.

Cell Membrane

- It is thin, flexible structure beneath the cell wall, surrounding cytoplasm.
- It is very delicate in nature and any damage to it results in death of the organism.
- Bacterial membrane differs from eukaryotic membrane in **lacking sterols** such as cholesterol.
- It is involved in **transport** of proteins, nutrients, sugars and electrons or other metabolites.
- The plasma membrane of bacteria also contains **enzymes for respiratory metabolism i.e.** site for cellular respiration.

Cytoplasmic Matrix

- A **gel like** substance present between the plasma membrane and the nucleoid.
- Plasma membrane and everything present within it is called **protoplast**.
- Cytoplasmic matrix lack membrane bounded organelles and cytoskeleton however chromatin/ nuclear body, ribosomes, mesosomes, granules and nucleoid are present in it.

Nucleoid

- Bacteria like other prokaryotic cells lack definite membrane bounded nucleus and chromosomes.
- Nucleoid is a single, circular, double stranded DNA molecule, aggregates as an irregular shaped dense area in the centre of bacterial cell.
- It is visible in the light microscope after staining with Feulgen dye.
- Other names for nucleoid are nuclear body, chromatin body and nuclear area.
- Extremely long molecule of DNA that is tightly folded to fit inside the cell component is chromatin body.
- Bacteria have a single chromosome; thus they are **haploid**.
- *E. coli* closed circle chromosome measures approximately 1,4000 μm.

Plasmid

- Circular, double stranded DNA molecules, **self-replicating** but not essential for the bacterial growth and metabolism
- Contains genes of **drug resistance, heavy metal resistance, disease, and insect resistance**.
- Plasmids are important vectors in modern genetic engineering techniques.

Ribosomes

- **Smaller** than eukaryotic ribosome.
- They are composed of **RNA and proteins.**
- May be loosely attached to the cell membrane or plasma membrane.
- They are involved in protein synthesis.

Mesosomes

- Formed by **invagination of cell membrane** in to the cytoplasm.
- Involved in DNA replication, cell division, export of exo-cellular enzymes and also contain respiratory enzymes.

Storage Bodies and Granules

- Store **extra nutrients** like glycogen, sulphur, fat and phosphate.
- Also store **waste material** like alcohol, lactic acid, and acetic acid.

Spores

- These are **metabolically dormant** bodies, resistant to adverse physical environmental conditions such as light, high temperature, desiccation, pH and chemical agents.
- They may be **exospores** (external to vegetative cell) or **endospores** (inside vegetative cell/ inside cell wall).
- Endospores are more resistant structures and can survive for years.
- They **germinate** to form vegetative cell under favorable conditions.
- They normally develop at **end stage of growth** of bacteria.

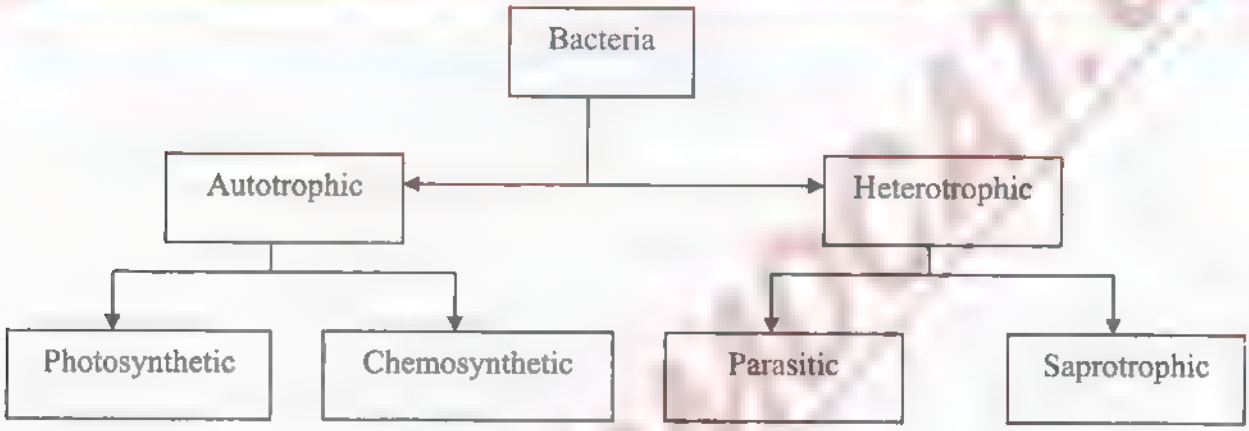
Cysts

- They are **dormant, thick walled** desiccation resistant form but not heat resistant structures.

- They develop during **differentiation of vegetative cells** which can germinate under suitable conditions.

Spore	Cyst
Inside (Endospores)	Outside
Resistant to light, temperature, desiccation, pH and chemical agents	Desiccation resistant
Develops at end stage of bacterial growth	Develops during differentiation of bacterial cell.

NUTRITION IN BACTERIA



A) **Heterotrophic Bacteria**

Those bacteria which cannot synthesize their organic compounds from simple inorganic substances are called **heterotrophic bacteria**.

(i) **Saprophytic Bacteria**

- **Saprophytic bacteria** get their food from dead organic matter present in soil in the form of humus.
- Humus is the material resulting from partial decay of plants and animals.
- Saprotrophic bacteria have an **extensive enzyme system** that break down the complex substances of humus to simple compounds.
- Examples are *Pseudomonas, Azotobacter*.

(ii) **Parasitic Bacteria**

- Those bacteria which are fully dependent upon their host for nutrition are **parasitic bacteria**.
- These are also called as pathogenic bacteria as they cause disease in their host.
- Examples are *Mycobacterium tuberculosis, Streptococcus pneumoniae* etc.

B) **Autotrophic Bacteria**

Those bacteria which can synthesize their organic compounds from simple inorganic substances are called **autotrophic bacteria**.

(i) **Photosynthetic Bacteria**

- **Photosynthetic bacteria** carry out photosynthesis.
- They contain chlorophyll which differs from chlorophyll of green plants, dispersed in the cytoplasm and thus is different from that present in cells of green plants.
- They use H_2S instead of water and that's why release sulphur instead of oxygen.

$$CO_2 + 2H_2S \xrightarrow[\text{Chlorophyll}]{\text{Light}} (CH_2O)_n + H_2O + 2S$$

- **Examples** of photosynthetic bacteria are green sulphur bacteria, purple sulphur bacteria, purple non- sulphur bacteria etc.

(ii) Chemosynthetic Bacteria

- **Chemosynthetic bacteria** oxidize inorganic compounds like ammonia, nitrates, nitrites, sulphur or ferrous ions and trap the energy thus released for their synthetic reactions.
- Examples are nitrifying bacteria.

RESPIRATION IN BACTERIA

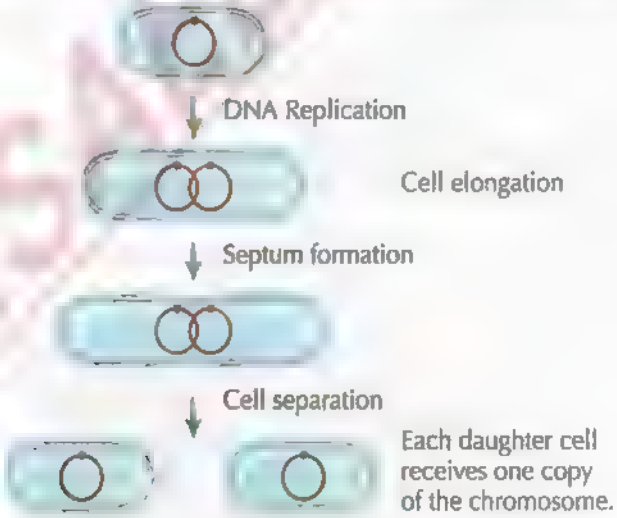
- Respiration in bacteria may be aerobic (requiring free oxygen) or anaerobic (not requiring free oxygen).

Aerobic	Grow the presence of oxygen	*Pseudomonas*
Anaerobic	Grow in the absence of oxygen	*Spirochete*
Facultative	Grow in the presence or absence of oxygen	*E. coli*
Microaerophilic	Require low concentration of oxygen for growth	*Campylobacter*

REPRODUCTION IN BACTERIA

Asexual Reproduction

- Bacteria lack mitosis.
- Bacterial growth refers commonly to increase in number of bacterial cells.
- Bacteria increase in number by an asexual means of reproduction, called binary fission.
- Parent Cell Enlargement → Chromosome Duplication/DNA Replication & Distribution → Cell Membrane Invagination → Inward Growth of Cell Wall → Division of Cell into Two Daughter Cells
- The interval of time until the completion of next division is known as **generation time.**



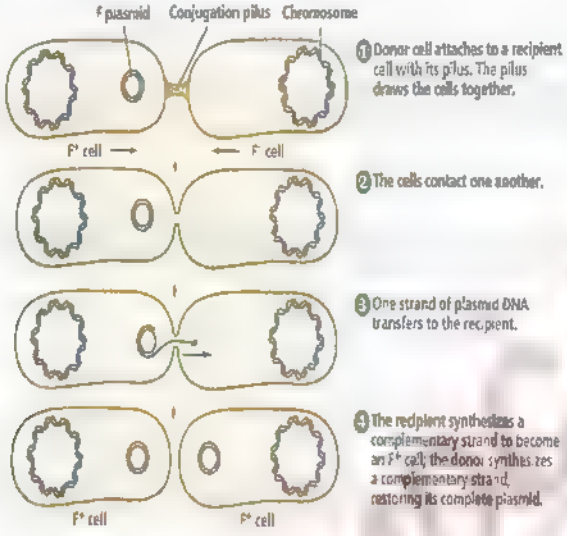
Sexual Reproduction

Bacteria lack traditional sexual reproduction because there is no formation of gametes and zygote. Instead it involves genetic recombination. It occurs in three ways; conjugation, transduction and transformation.

Conjugation

- Some bacteria transfer genetic material from a donor bacterium to a recipient bacterium during a process called conjugation.

- During conjugation, bacteria use specialized sex pili to transfer genetic material.
- Bacterial plasmids are exchanged during conjugation.
- Conjugation produces new genetic combinations that may allow the resulting bacteria to survive under great variety of conditions.



Phases of Growth

- Bacterial growth refers commonly to increase in number of bacterial cells
- Four distinct phases are recognized in bacterial growth curve.

(i) Lag Phase

- It is the phase of no growth.
- Bacteria prepare themselves for division.

(ii) Log Phase

- It is the phase of rapid growth.
- Bacteria divide at exponential rate.
- Number of cells double with each doubling time.

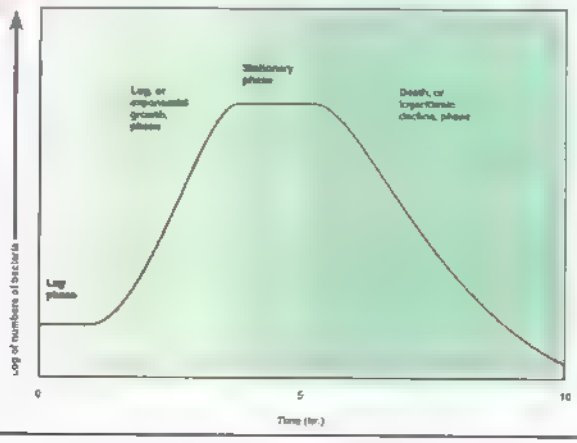
(iii) Stationary Phase

- Bacterial death rate is equal to bacterial rate of reproduction and multiplication.
- This occurs due to exhaustion of nutrients or accumulation of toxic metabolites.

(iv) Death/ Decline Phase

- Bacteria start dying. Here the death rate is more than reproductive rate.
- Some bacteria may survive by forming resistant spores.

Bacterial Growth Curve



IMPORTANCE AND CONTROL OF BACTERIA

Importance of Bacteria

Ecological Importance

- Bacteria are ecologically very important. They are highly adaptable as a group and are found nearly everywhere.
- They are able to decompose organic matter and play a significant role in the completion of cycles of nitrogen, phosphorus, sulfur and carbon.

Economic Importance

- Bacteria are used in number of industries, including food, drugs (production of antibiotics) and in biotechnology.
- Bacteria are also responsible for spoilage of food and vegetables.
- Many plant pathogens adversely affect the agricultural industry.

Medical Importance

- Bacteria are very common pathogens of humans. **Approximately 200 species** are known to cause diseases in humans.
- Many bacteria normally inhabit the bodies of man and other animals.

Control of Bacteria

Bacterial control is required to prevent diseases and food spoilage.

Physical Methods

- The process in which physical agents are used to control bacteria microorganisms is known as **sterilization process.**
- It involves killing of all microbes.
- In physical methods, steam, dry heat, gas, filtration and radiations are used to control bacteria.

(i) Use of Heat

- Both dry heat and moist heat are effective.
- Moist heat causes coagulation of proteins and kills the microbes.
- Dry heat causes oxidation of chemical constituents of microbes and kills them.

(ii) Use of Radiations

- Certain electromagnetic radiations below 300 nm are effective in killing of microorganisms.
- Gamma rays are in general used for the sterilization process.

(iii) Membrane Filters

- Heat sensitive compounds like antibiotics, seras etc. can be sterilized by means of membrane filters.

Chemical Methods

(i) Disinfection

- It involves killing of microbes by use of chemical agents.
- It involves killing of most but not all life forms.
- The important chemicals used for disinfection are oxidizing and reducing agents. For example, halogens, phenols, hydrogen peroxide, potassium permanganate, alcohol and formaldehyde etc.

(ii) Antisepsis

- Procedure to eliminate or reduce the possibility of infection is called antisepsis.
- Chemical substances used on living tissues that inhibit the growth of microorganism are called antiseptics.

(iii) Chemotherapeutic Agents

- Chemotherapeutic agents and antibiotics work with natural defense and stop the growth of bacteria and other microbes. These are sulfonamides, tetracycline and penicillin.
- They destroy or inhibit the growth of microorganisms in living tissues.

(iv) Vaccination

- Vaccination is an important method to control bacterial diseases in humans.
- Pasteur used attenuated cultures of bacteria as vaccine.

Antibiotics

Antibiotics are the chemotherapeutic chemical substances which are used in treatment of infectious diseases.

Synthesis

- Antibiotics are synthesized and secreted by certain bacteria, actinomycetes (Spore forming, Gram positive bacteria that grow to form long tubules called filaments) and fungi.
- Some antibiotics are also synthesized in laboratory. However, their origin is living cells.

Mode of Action

- **Microbicidal effect** is one that kills the microbes immediately.
- **Microbistatic effect** inhibits the reproductive capacities of the cells and maintains the microbial population at constant size.
- Damage by antibiotics can result in malfunctioning of cell wall, cell membrane, cytoplasmic enzymes or nucleic acids.

Misuse of Antibiotics

- Widespread problem is drug resistance against microorganisms. This results in an increased resistance against disease treatments.
- Misused antibiotics can interact with the human metabolism and in severe cases can cause death of human beings.

Penicillin	Allergic reactions
Streptomycin	Effects auditory nerve causing deafness.
Tetracycline	Permanent discoloration of teeth in young children.

CYANOBACTERIA

Introduction

Cyanobacteria are the most prominent photosynthetic bacteria which are found in any damp place.

Features

- Majority of them are **free living** while some are found as **epiphytic** or **symbiotic** forms.
- Cyanobacteria have **Gram-negative** type of cell wall.
- The body may be **unicellular** and solitary or in the form of **filaments** which may form **colonies**. In filamentous forms the cells are arranged in linear row, the trichome which is embedded in mucilage sheath e.g. *Anabaena, Nostoc* etc.

Importance of Cyanobacteria

- They help in **reclamation of alkaline soils.**
- Cyanobacteria have heterocysts, which are helpful in the **fixation of atmospheric nitrogen.**
- They **release** O_2 in the environment due to their photosynthetic activity.
- Oscillatoria and few other cyanobacteria can be used as **pollution indicator.**
- They have **symbiotic relationship** with protozoa, fungi, and nitrogen fixing species form associations with angiosperms. They are photosynthetic partner in most of lichen association.
- Many species of cyanobacteria form **water blooms** where they often impart unpleasant smell and due to large amount of suspended organic matter, water becomes unfit for consumption.
- Some species produce toxins that kill livestock and other animals that drink the water

TOPIC-7 » PROTISTS & FUNGI

CONTENT

- Introduction
- Protozoa
- Algae
- Fungi Like Protists
- Introduction and Body of Fungus
- Nutrition and Reproduction in Fungi
- Classification of Fungi
- Importance of Fungi

INTRODUCTION

Eukaryotic cells, the unifying feature of protists, are common to complex multicellular organisms from three other kingdoms (fungi, animals, and plants).

Types of Protists

- Heterotrophic protists (protozoa, slime molds, and water molds).
- Autotrophic protists (algae).

Polyphyletic Origin of Protists

- The protist kingdom is a **polyphyletic group** of organisms; that is, protists do not share a single common ancestor.
- Their **size** varies from microscopic protozoa to giant kelps, which are brown algae that can reach 60 meters (almost 200 feet) in length.
- Most protists are **unicellular**, some have a **colonial organization** (a colony is a loose aggregation of cells), some are **Coenocytic** (multinucleate but not multicellular), and some are **multicellular**.
- Unlike animals, fungi, and plants, multicellular protists have relatively simple body forms without specialized tissues.

Major groups of protists

Protists include three major groups:

- Protozoa: Animal-like Protists
- Algae: Plant-like Protist
- Fungus-like Protists

PROTOZOA

- All protozoans are unicellular.
- All ingest food by endocytosis.

Common Name	Form	Existence	Locomotion	Examples
Amoebas	Unicellular	Free living	Pseudopodia(false feet) cytoplasmic projections	*Entamoeba histolytica* (Amoebic dysentery in humans.)
Zooflagellates	Unicellular, some colonial	Free living, Parasitic or symbiotic.	One (usually at anterior end) or more flagella	*Trichonymphas* (symbiotic in termite's gut) *Trypanosoma (African sleeping sickness)Euglena*
Actinopods	Unicellular	Free living	Pseudopods	*Radiolarians*
Foraminifera	Unicellular	Free living	Pseudopods	*Forams*
Apicomplexans	Unicellular	Parasitic	None, flexing	*Plasmodium (malaria)*
Ciliates	Unicellular	Free living	Cilia	*Paramecium, Vorticella, Stentor*

Zooflagellates

- **Trichonymphas** are complex, specialized flagellates with many flagella which live as symbionts in the guts of termites and help in the digestion of dry wood.
- **Choanoflagellates** are sessile marine or freshwater flagellates, which are attached by a stalk, and a delicate collar surrounds their single flagellum.
- Choanoflagellates are of special interest because of their striking resemblance to collar cells in sponges.

Ciliates

- They are unicellular organism with a flexible outer covering called a **pellicle** that gives them a definite shape, which is changeable.
- Water regulation in freshwater ciliates is controlled by special organelles called **contractile vacuole**.
- Ciliates have two nuclei i.e. **diploid micronuclei** functioning in sexual process whereas **polyploid macronucleus** that controls cell metabolism and growth.
- Ciliates are capable of sexual reproduction called **conjugation** during which they transfer their genetic material.

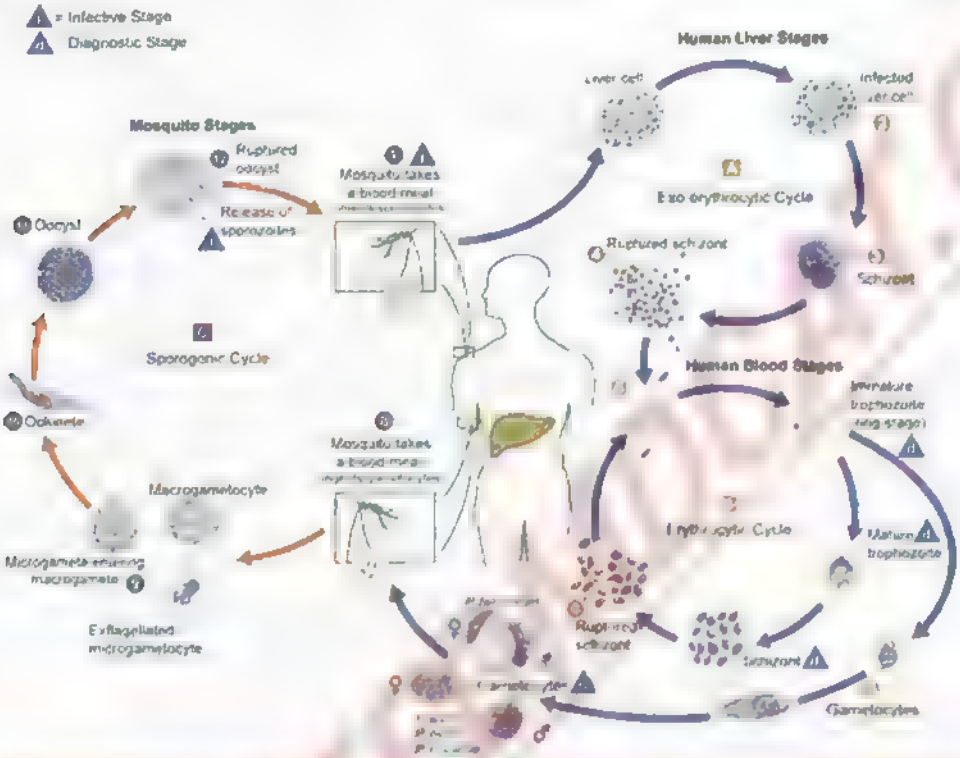
Foraminiferans and Actinopods

- **Foraminiferans and actinopods** are marine protozoans which produce shells (or tests).
- **Tests** of foraminiferans are made up of calcium whereas those of actinopods are made up of silica.
- Dead foraminiferans sink to the bottom of the ocean where their shells form a grey mud that is gradually transformed into **chalk**.
- Foraminiferans of the past have created vast **limestone deposits**.
- **Radiolarians** are actinopods with glassy shells.

Apicomplexans

- **Apicomplexans** lack specific structures for locomotion but move by flexing
- Many apicomplexans spend part of their life in **one host** and part in a **different host species**.
- **Plasmodium** is transmitted to man by a bite of an infected **female anopheles mosquito**.

- Upon entry, gain access to liver cells, then in RBC, where they multiply, and upon bursting of R.B.C newly formed plasmodium infect other R.B.Cs.
- Simultaneous bursting of millions of cells result chills, fever from number of toxic substances.



ALGAE

Habitat

Algae are found in ocean, fresh water ponds, lakes, streams, hot springs, polar ice, moist soil, trees and rocks.

Life Forms

Algae may be unicellular, filamentous or multicellular. Filaments are composed of multicellular structures, which lack cross-walls (coenocytes) or distinct cells.

Thallus

In multicellular algae, e.g., seaweeds the body is branched or leaf-like called **thallus.**

Photosynthetic Pigments

The photosynthetic pigments found in algae are chlorophyll "a", yellow and orange carotenoids, xanthophylls and phycoerythrin.

Flagella

Algal life cycle shows extreme variations. All algae except the red algae (Phylum Rhodophyta) have forms with flagellated motile cells in at least one stage of their life cycle. Algae differ from the plants in this respect that the sex organs in algae are unicellular, the zygote is not protected by the parent body and embryo is not formed.

Classification of The Photosynthetic Protoctists

Euglenophyta	Euglenoids	Unicellular	Two flagella one long one short	Chl.a, Chl.b, Carotenoids	*Euglena*
Phyrrophyta	Dinoflagellates	Unicellular	Two flagella	Chl.a, Chl.c, Carotenes including Fucoxanthin	*Gonyaulax, Ceratium*
Chrysophyta	Diatoms	Usually multicellular	Usually none	Chl.a, Chl.c, Carotenes including Fucoxanthin	*Diatoma, Frequilaria, Pinnularia*
Phaeophyta	Brown algae	Multicellular	Two flagella on reproductive cells	Chl.a, Chl.c, Carotenes including Fucoxanthin	*Focus, Macrocystis*
Rhodophyta	Red algae	Multicellular or unicellular	None	Chl.a, Carotenes, Phycoerythrin	*Chondrus, Polysiphonia*
Chlorophyta	Green algae	Unicellular, colonial, multicellular	Most have flagella	Chl.a, Ch.b, carotenes	*Chlorella, Ulva, Acetabularia, Spirogyra*

General Characteristics of Plant-like Protists

Euglenoids	Euglenoids are small fresh-water organisms, e.g., *Euglena*.
Dinoflagellates	Dinoflagellates vary in colour from yellow, green to brown.
Diatoms	• Diatoms are the most numerous unicellular algae in the oceans and also plentiful in fresh water • The cell wall has two halves, with the larger halves acting as a "lid" for the smaller half.
Brown algae	• They range from small forms with simple filaments to large multicellular forms up to 75 meter in length. • The large brown algae are called **kelps.**
Red algae	• Red Algae are multicellular. • They can be up to a meter long attached to rocks or other substances by a basal holdfast.
Green algae	• Green algae are important producers. • Green algae live in the ocean but are more likely found in fresh water and can even be found on land, e.g., *Chlamydomonas, Spirogyra, Volvox*

FUNGI LIKE PROTISTS

Similarities with fungi

- Both are not photosynthetic.
- Formed of thread like structures called hyphae.

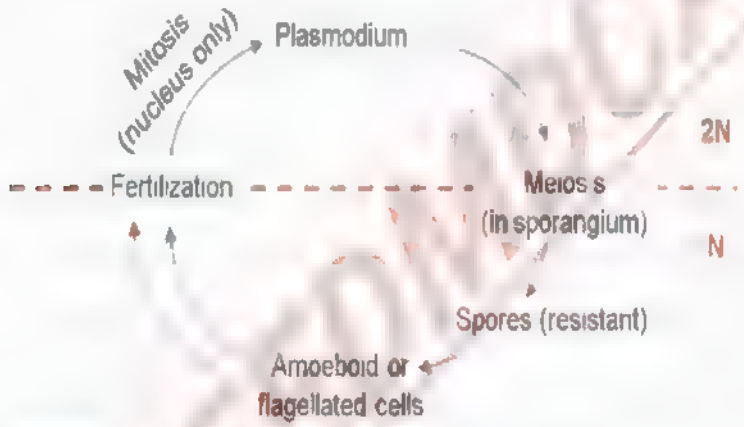
Differences with fungi

- These protists have centrioles.

- Cell wall is made of cellulose, while that of fungi is made of chitin.

Slime Molds or Myxomycota

- The **feeding stage** of a slime mold is a plasmodium, a multinucleate mass of cytoplasm that can grow to 30cm (1ft) in diameter. Plasmodium is a naked mass of cytoplasm having many nuclei.
- **Reproductive structures** of slime molds are stalked sporangia.
- **Sporangia** produce haploid spores by meiosis formed during unfavorable conditions.
- In slime molds under favorable condition, the spores germinate into **biflagellated or amoeboid reproductive or swarm cells,** which unite to form diploid zygote.
- The plasmodial slime mold ***Physarum polycephalum*** is the model organism that has been used in many fundamental biological processes such as growth and differentiation, cytoplasmic streaming and the function of cytoskeleton.



Water Molds or Oomycota

- Their cell wall contains ***cellulose,*** not chitin with ***aseptate hyphae.***
- ***Phytophthora infestans*** was the cause of Irish potato famine of the 19th century.
- It *causes* a disease commonly known as ***late blight of potatoes.***

Importance of Protists to Humans

Gains

- Diatoms are an important source of food and oxygen for heterotrophs in both fresh water and marine ecosystem.
- Brown algae not only provides food to organisms, but is also harvested for human food and for fertilizer in several parts of the world.
- Red algae are economically important. The mucilaginous material in the cell walls of certain genera of red algae is a source of agar used commercially to make capsules for vitamins and drugs, as a material making dental impression and a base for cosmetics. In laboratory agar is a culture medium for bacteria.
- Green algae are important producers. *Chlorella* has been used as experimental organism in research in photosynthesis. A relatively new food source is single cell protein (SCP).
- In oceans, fresh water lakes and ponds are **zooplanktons** that feed on phytoplanktons, and are important as primary consumers in the food chain.

Diseases

- Malaria caused by *Plasmodium* is one of the world's most common serious infectious diseases. According to world health organization about one to two million people die each year from malaria.

- *Entamoeba histolytica* causes amoebic dysentery.
- *Trypanosoma* causes sleeping sickness.
- *Phytophthora infestans* causes late blight disease in potatoes.

INTRODUCTION AND BODY OF FUNGUS

Structure of Fungi

- Fungi are eukaryotes, non-motile absorptive heterotroph.
- The body of the fungus is called **mycelium,** consists of long, slender, branched tubular thread like filaments called **hyphae.**
- Hyphae may be septate or non-septate. **Septate hyphae** are divided by cross-walls called **septa** into individual cells containing one or more nuclei.
- Septa of many septate hyphae have a pore through which cytoplasm flows from cell to cell.
- **Non-septate hyphae** lack septa and are not divided into individual cells; instead these are in the form of an elongated multinucleated large cell. Such hyphae are called **Coenocytic hyphae**, in which the cytoplasm moves effectively, distributing the materials throughout. These are always multinucleate.
- Hyphae may be packed together and organized to form complex reproductive structures such as mushroom, puff balls, morels etc.
- Yeast is non-hyphal and unicellular fungi.
- Chitin in their cell wall is more resistant to decay than cellulose and lignin which make up plant cell wall.
- All fungal nuclei are haploid except for transient diploid zygote that is formed during sexual reproduction.
- All parts of the fungus growing through the substrate are metabolically active. Extensive spreading system of hyphae provides enormous surface area for absorption.
- They show a characteristic type of mitosis, called nuclear mitosis. During nuclear mitosis, nuclear envelope does not break; instead the mitotic spindles form within the nucleus and nuclear membrane constricts between the two clusters of daughter chromosomes.

NUTRITION AND REPRODUCTION IN FUNGI

Nutrition in Fungi

- All Fungi lack chlorophyll and are **heterotrophs** (obtaining carbon and energy from organic matter). They obtain their food by direct absorption from the immediate environment and are thus fungi are **absorptive heterotrophs.**

Modes of Nutrition

Various modes of nutrition are found in fungi. Some of them are;

(i) Saprotrophic nutrition
(ii) Parasitic nutrition
(iii) Predation
(iv) Mutualistic nutrition

(i) Saprotrophic Nutrition

Most fungi are saprotrophs (or saprobes), **decomposers** that obtain their food (energy, carbon and nitrogen) directly from dead organic matter.

Saprobic fungi, along with bacteria, are the major decomposers of the biosphere, contributing to the recycling of the elements ***(C, N, P, O, H etc.)*** used by living things.

Characteristics of Saprobes

- Saprobic fungi anchor to the substrate by modified hyphae, the **rhizoids**.
- Fungi are the principal decomposers of cellulose and lignin, the main components of plant cell walls (most bacteria cannot break them).
- Extensive system of fast growing hyphae provides enormous surface for absorptive mode of nutrition.

(ii) Parasitic Nutrition

Parasitic fungi absorb nutrients directly from the living host cytoplasm with the help of special hyphal tips called **haustoria**.

Types of Parasitic Fungi

There are two types of parasitic fungi i.e.,

- **Obligate parasites** can grow only on their living host and cannot be grown on available defined growth culture medium.

  Facultative parasites can grow parasitically on their host as well as by themselves on artificial growth media.

(iii) Predation

Some fungi are active predators (which can capture a living prey). Other predators have other adaptations, such as secretion of sticky substances.

Examples

The oyster mushroom (***pleurotus ostreatus***) is a carnivorous (predatory) fungus. Some species of ***Arthrobotrys*** trap soil nematodes by forming constricting ring, their hyphae invading and digesting the unlucky victim.

(iv) Mutualistic Nutrition

Fungi form two key mutualistic symbiotic associations (associations of benefit to both partners).

These are ***lichens*** and ***mycorrhizae***.

Lichens; are mutualistic symbiotic associations between certain fungi (mostly Ascomycetes and imperfect fungi, and few Basidiomycetes - about 20 out of 15000 species of lichens) and certain photoautotrophs either green algae or a cyanobacterium, or sometimes both.

- Most of the visible part of lichen consists of fungus, and algal components are present within the hyphae.
- Fungus protects the algal partner from strong light and desiccation and itself gets food through the courtesy of alga.
- Lichens can grow at such places where nether of the components alone can, even at harsh places such as bare rocks etc. lichens vary in colour, shape, overall appearance, growth form.
- They are ecologically very important as ***bioindicators*** of air pollution.

Mycorrhizae are mutualistic association between certain fungi and roots of vascular plants (about 95% of all kinds of vascular plants).

- The fungal hyphae dramatically increase the amount of soil contact and total surface area for absorption and help in the direct absorption of phosphorus, zinc, copper and other nutrients from the soil into the roots.
- Such plants show better growth than those without this association. The plant, on the other hand, supplies organic carbon to fungal hyphae.

Types of Mycorrhizae

There are two main types of mycorrhizae:

- **Endomycorrhizae;** in which the fungal hyphae penetrate the outer cells of the plant root, forming coils, swellings, and minute branches, and also extend out into surrounding soil
  Ectomycorrhizae; in which the hyphae surround and extend between the cells but do not penetrate the cell walls of the roots. These are mostly formed with pines, firs etc. However, the mycelium extends far out into the soil in both kinds of mycorrhizae.

Reproduction in Fungi

Fungi can reproduce asexually as well as sexually.

Asexual Reproduction

Asexual reproduction takes place by **spores, conidia, fragmentation and budding.**

(i) Spore Formation

- Spores are common mean of reproduction in fungi.
- **Spores** are produced inside the reproductive structures called **sporangia,** which are cut off from the hyphae by complete septa.
- Spores may be produced by sexual or asexual process.
- These are haploid, non-motile and not needing water for their dispersal.
- These are small in size, produced in very large number and dispersed by wind to great distances.
- Spores may also be dispersed by insects and many other small animals and by rain splashes.

(ii) Conidia Formation

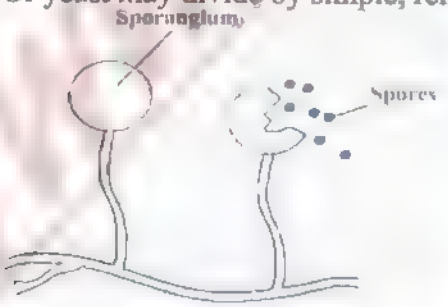
- **Conidia** are non-motile, asexual spores which are cut off at the end of modified hyphae called **conidiophores,** and not inside the sporangia, usually in chains or clusters.
- They may be produced in large number, can survive for weeks and cause rapid colonization of new food.

(iii) Fragmentation

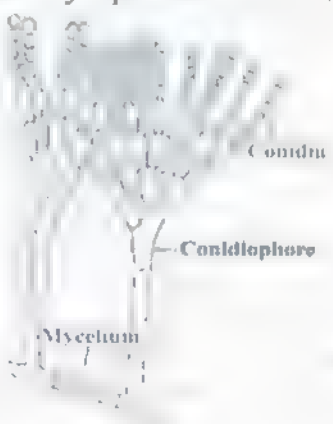
- **Fragmentation** is simple breaking of mycelium of some hyphal fungi, each broken fragment giving rise to a new mycelium.

(iv) Budding

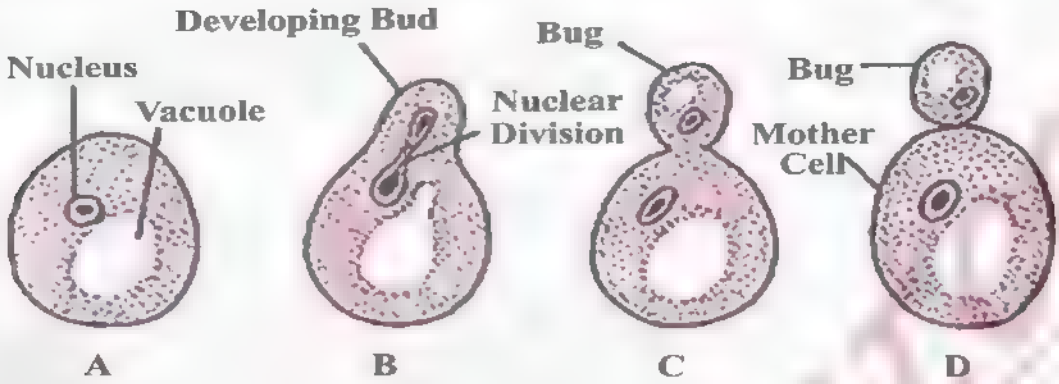
- Unicellular yeasts reproduce by **budding.**
- It is an asymmetric division in which tiny outgrowth or bud is produced which may separate and grow.
- Or yeast may divide by simple, relatively equal cell division.



Spore formation in fungi




Formation in fungus



Sexual Reproduction

- Details of **sexual reproduction** vary in different groups of fungi, but fusion of haploid nuclei and meiosis are common to all.
- During sexual reproduction in fungi, hyphae of two genetically different but compatible mating types come together, their cytoplasm fuse followed by nuclear fusion.
- **Karyogamy** is the fusion of nuclei while **plasmogamy** is the fusion of cytoplasm.
- In Basidiomycetes and Ascomycetes, karyogamy does not take place immediately after plasmogamy; instead the two genetic types of haploid nuclei from two individuals may coexist and divide in the same hyphae for most of the life of the fungus. Such hyphae having 2 different genetic types are called dikaryotic or heterokaryotic.
- Different groups of fungi produce different types of haploid sexual spores, such as basidiospores and ascospores, subsequent upon meiosis in zygote.
- These spores may be produced by their characteristic structure/ fruiting bodies such as basidia/ basidiocarp and asci/ascocarp.

CLASSIFICATION OF FUNGI

- Classification of fungi is primarily based on type of their sexual reproductive structures and type of hyphae and some other characters.
- Fungi are classified into four groups

Phylum (group)	Typical Examples	Sexual Reproduction	Asexual Reproduction	
Zygomycota (Zygomycetes or conjugating fungi)	*Rhizopus* (Black bread mold), *Pilobolus* (spitting fungus)	Zygospores	Non-motile spores form in sporangia	Non-septate, multinucleate
Ascomycota (Ascomycetes or sac-fungi)	Yeasts, morels, truffles, powdery mildews, molds	Ascospores inside sac-like asci	Conidia cut off from tips of conidiophores	Septate, lengthy dikaryotic phase.
Basidiomycota (Basidiomycetes or club-fungi)	Mushrooms, rusts, smuts, puff balls, bracket fungi	Basidiospores borne on club shaped basidia	Uncommon	Septate, lengthy dikaryotic phase
Deuteromycota (Deuteromycetes/ Imperfect fungi)	*Aspergillus*, *Penicillium*, *Alternaria*	Sexual phase has not been observed	Conidia	Varied

Zygomycota (Zygomycetes or Conjugating Fungi)

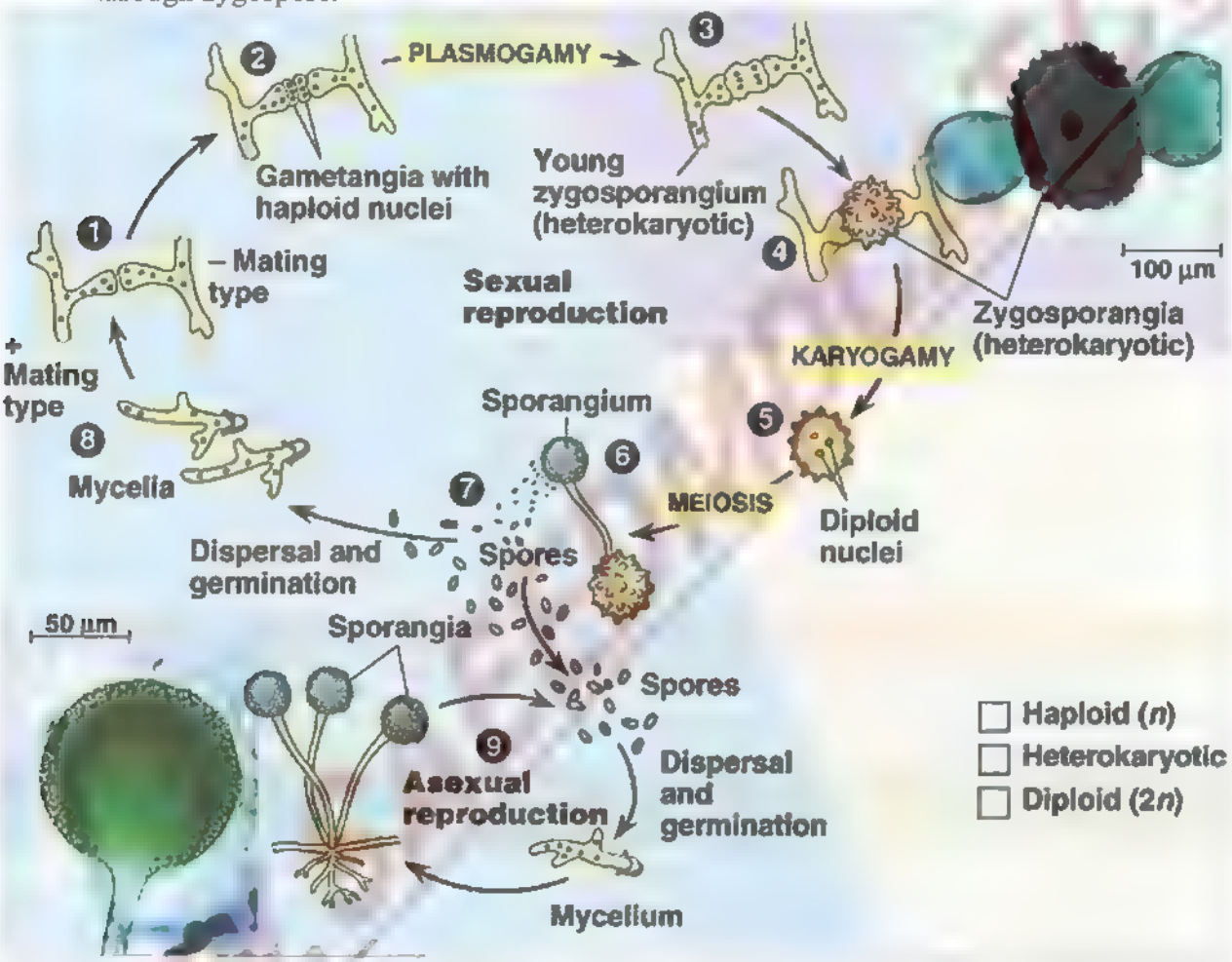
Zygospores are temporary, dormant, thick walled resistant structures formed during sexual reproduction by fusion of hyphae.

Life Cycle of Rhizopus

Mycelium → Hyphae (fusion) → Zygote formed by fusion of gametangia → Zygospore → Zygospore germinates → Sporangiophores with sporangia → Meiosis → Spores → New mycelium

Life Cycle

- It shows both asexual and sexual reproduction.
- Asexual reproduction is through spores produced in sporangia and sexual reproduction is through zygospore.



Ascomycota (Ascomycetes or Sac-Fungi)

- It is the **largest group** of fungi.
- There are approximately **60,000 species** of ascomycota, 50% or so occurring in lichen and some are mycorrhizal (e.g. morels).
- Most are **terrestrial** however some are marine or fresh water.
- They reproduce **asexually by conidia** that are often dispersed by wind.
- They also produce haploid sexual spores called **Ascospores,** which are produced in sac-like structures called asci (ascus=sac). Commonly 8 ascospores are produced inside each ascus.
- Ascocarps are microscopic fruiting body containing **asci**.

Mycelium → Plasmogamy → Dikaryotic Mycelium → Karyogamy→ Zygote (2n) → Meiosis → Mitosis → 8 Ascospores → Mycelium

Examples

- Yeast, cup fungi and morels are different examples.
- **Yeasts** are unicellular microscopic fungi derived from all the three different groups of fungi but mostly ascomycetes.
- Yeasts reproduce asexually by budding however sexual reproduction by forming asci/ ascospores or basidia/ basidiospores may also occur.
- ***Saccharomyces cerevisiae*** is the most common yeast.

Basidiomycota (Basidiomycetes or Club- Fungi)

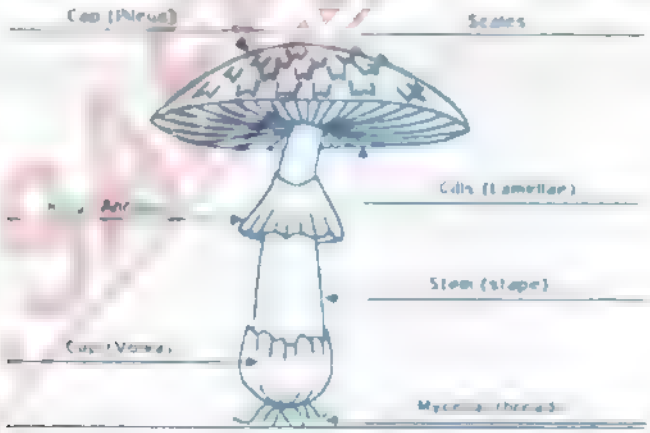
- Named so for their characteristic club shaped sexual reproductive structure, the **basidium**.
- **Basidiospores** are four haploid spores which are born on, not inside each basidium.
- Their **hyphae** are septate and cells are uninucleated during one phase and dikaryotic during the remaining.
- Fruiting bodies of basidiomycetes or **visible mushrooms** are formed entirely of dikaryotic mycelium.

  Mycelium → Plasmogamy → Dikaryotic Mycelium → Karyogamy → Zygote (2n) → Meiosis → 4 Basidiospores → Mycelium

Examples

Edible mushrooms, rusts and smuts, puffballs, and bracket shelf fungi.

- ***Puccinia*** species are most common rust fungi.
- ***Ustilago*** species are most common smut fungi.
- ***Rusts*** are so called because of numerous rusty, orange yellow colored disease spots on host surface (mostly stem, leaves).
- ***Smuts*** are so called because of their black dusty spore masses that resemble soot or smut.
- Spores of *Ustilago tritici* (loose smut of wheat) are called ***teliospores***.



Deutromycota (Deuteromycetes or Imperfect Fungi)

- All such fungi in which **sexual phase has not been observed** are placed in deuteromycota.
- If sexual structures are found on an imperfect fungus, it is then reassigned to the appropriate phylum.
- Most imperfect fungi are now classified on the basis of **DNA sequences**.
- Imperfect fungi show special kind of genetic recombination called **parasexuality**. In it portions of chromosomes of two nuclei lying in the same hyphae are exchanged.

Examples

Penicillium (blue, green molds), *Aspergillus* (brown molds), *Alternaria*, *Fusarium*, *Helminthosporium*

Penicillium

- Are **saprophytic** species.
- Having **septate hyphae**.
- Reproduce asexually by means of naked spores called **conidia**.
- **Brush like arrangement** of conidia is characteristic of Penicillium

IMPORTANCE OF FUNGI

Fungi are important both ecologically and economically.

Ecological Importance

- Fungi are important group of **decomposers and symbionts**.
- They play an important role in **recycling of inorganic nutrients** in the ecosystem.
- **Mycorrhizal fungi** improve the growth of plants, with which 95% of vascular plants are associated.
- **Lichens** growing on break rocks, setting stage for other organisms during the course of ecological succession.
- Lichens being sensitive to pollution are **good bio indicators** of air quality.
- Some fungi are also used for **bioremediation**.

Commercial Importance

Ecological Gains Due to Fungi

Role in Food Industry

- About 200 species of mushrooms are edible e.g. *Agaricus* sp.
- Morels (*Morchella esculenta*) and truffles (underground fruiting bodies of some ascomycetes) are edible fungi.
- Poisonous mushrooms are called toadstools e.g. death cap/death angel (*Amanita*) and Jack O' lantern mushroom.
- Reindeer moss (lichen) is used as food for reindeers.

Mushrooms	Edible
Morels	Edible
Truffles	Edible
Saccharomyces cervisiae	Fermentation to get bread and liquor.
Penicillium	Flavor, aroma and characteristic colour to some cheese.
Aspergillus	Fermentation of soya bean to get soya sauce and soya paste. Production of citric acid.

Role in Drug Industry

- Penicillin was the first antibiotic, discovered by A. Fleming from *Penicillium notatum* (fungus)

Penicillin	Antibiotic
Lovastatin	Lowers blood cholesterol
Cyclosporine	Prevent transplant rejection/ Immunosuppressive drug
Griseofulvin	Inhibit fungal growth/ Antifungal
Ergotine	Relieve headache (Migrain)

Role in Research

- ***Yeast*** was the first eukaryotes to be used by genetic engineers.
- First functional **artificial chromosome** was made in *Saccharomyces cervisiae*.

- Pink bread mold ***Neurospora*** (Pink bread mold) has been used in genetic research.

Ecological Losses Due to Fungi

Plant Diseases

Powdery mildews	Grapes, rose and wheat
Ergot	Rye
Red rot	Sugarcane
Wilt	Potato
Root rot	Cotton
Scab	Apple
Brown rot	Peaches, plums, apricot and cherries

Human Diseases

- **Ringworm and athlete's foot** are superficial fungal infections.
- **Histoplasmosis** is caused by inhaling spores of a fungus, which is common in soil contaminated with bird's feces.
- **Candidasis or candidosis** is oral or vaginal thrush caused by *Candida albicans*.
- *Aspergillus fumigatus* causes **aspergillosis** in persons with defective immune system (e.g. AIDS).
- Some strains of Aspergillus produce carcinogenic mycotoxins, called **aflatoxins**.
- **Ergotism** is caused by eating bread made from purple ergot-contaminated rye flour.

Spoilage

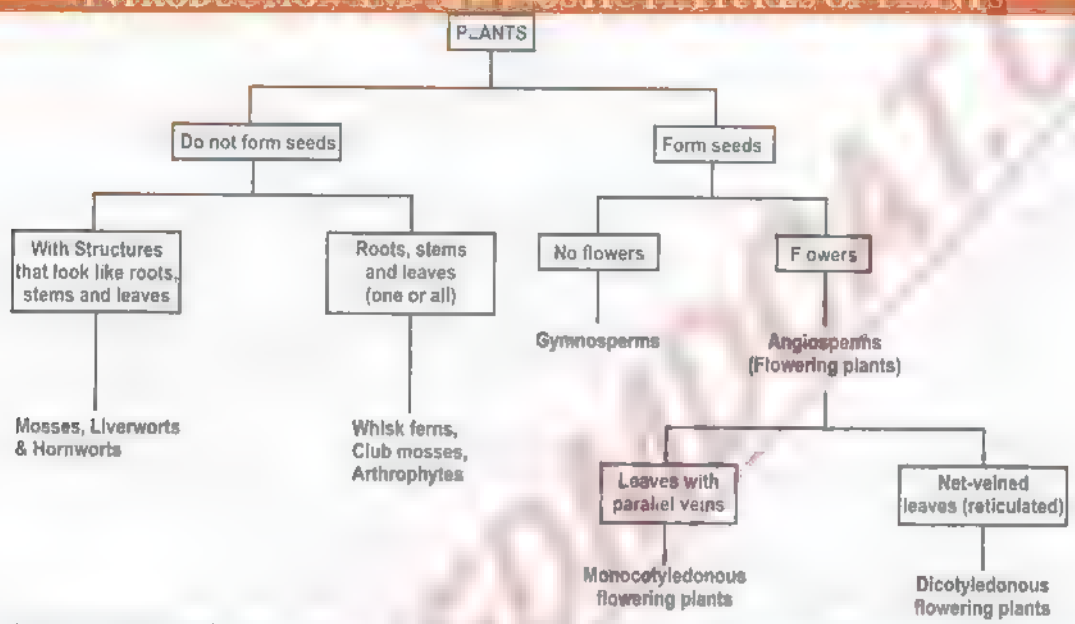
- **15-50%** of world's fruit is lost each year due to fungal attack.
- **Wood-rotting fungi** destroy living trees and structural timber.
- **Bracket/shelf fungi** cause lot of damage to stored cut lumber as well as stands of timber of living trees.
- Pink yeast ***Rhodotorula*** grows on shower curtains and other moist surfaces.

TOPIC-8 » DIVERSITY AMONG PLANTS

SYLLABUS CONTENTS

- Introduction and Diagnostic Features of Plants
- Classification of Plants

INTRODUCTION AND DIAGNOSTIC FEATURES OF PLANTS



- Arrangement of organisms on the base of their mode of origin is called **phylogenetic system of classification**. It foreshadows the natural relationship among living organisms and their mode of origin.
- **Kingdom plantae** mainly includes organisms, which are eukaryotic, autotrophs, multicellular, non-motile, develop from embryo and have cell wall made of cellulose.
- There are about **360,000** known species of plants.

CLASSIFICATION OF PLANTS

- Kingdom Plantae can be broadly divided into **two major categories** or divisions i.e. **bryophyta** (non- vascular plants) and **tracheophyta** (vascular plants).

Bryophyta

- They are the **first plant to colonize land.**
- They are thought to be **evolved from green algae.**
- **Vascular system is absent.** So osmosis and diffusion are mainly involved in transportation.
- **Gametophyte** generation is **dominant**
- **Sporophyte** is attached to gametophyte and dependent for food.
- They are **homosporous**, poorly adapted to life on land, mainly confined to damp and shady places.
- They are **flowerless** plants.
- They show a **regular alternation of heteromorphic** (morphologically different) generations.
- They require water for fertilization thus called **amphibians of plants**

Alternation of Generation

- Process in which one multicellular, haploid gametophyte generation (n) alternates with another multicellular, diploid sporophyte generation (2n) is called **alternation of generations**.
- Alternation of morphologically different generations is called **heteromorphic alternation of generation** while that of morphologically similar generations is called **homomorphic alternation of generation.**
- Bryophytes show heteromorphic alternation of generation.

Gametophyte Generation (n)

- **Gamete producing** generation is called gametophyte.
- Gametophyte of bryophytes is **dominant**, independent, free living and is haploid.
- It may be **thalloid** (as in many liverworts) **or differentiated into** structures like stem, leaves and rhizoids (anchoring and absorbing organ).
- Gametophyte produces a sporophyte.

Sporophyte Generation (2n)

- **Spore producing** generation is called sporophyte.
- It is a **less conspicuous** generation.
- It does not contain chlorophyll and is unable to perform photosynthesis, thus are partially or totally dependent on gametophyte for their nutrition.
- It is a **diploid** generation.
- It consists of **foot, seta and capsule**.
- Entire sporophyte development takes place in gametopyhte.
- When fully developed remain attached to gametophyte to get nourishment from it.

Adaptation to Land Habitat

- Compact multicellular plant body and cuticle reduces the exposed surface area thus **conserving water.**
- **Photosynthetic tissue** is present in special chambers.
- They exhibit **heterogamy** consisting of non- motile egg containing food and motile sperms.
- Gametes and embryo are **protected** by multicellular sex organs.
- **Alternation of generation** provides a chance of genetic variability, selection of best genetic makeup for survival and adaptation in the changing environment.

Significance of Alternation of Generations

- Provides a chance of genetic variability, resulting from meiotic division at the time of spore formation.
- Result in selection of best genetic makeup for survival and adaptation in the changing environment. Thus the gametophyte with less advantageous character will be eliminated.

Classification of Bryophytes

Bryophytes are divided into three classes i.e. Hepaticopsida, Bryopsida, and Anthoceropsida.

Features of Three Classes of Bryophytes

Feature	Hepaticopsida	Bryopsida	Anthocerpicida
Introduction	Liverworts, 900 species, simplest	Mosses, cushion or mat like	Hornworts, slightly advanced and different
Habitat	Moist rocks, wet soil	Damp places, some dry places	Moist places
Examples	*Marchantia, Porella*	*Funaria, Polytrichum*	*Anthoceros*
Gametophyte	Haploid, thalloid	Haploid, having stems and leaves.	Haploid, lobed, irregular
Sporophyte	Diploid, dependent	Diploid	Free, independent

Hepaticopsida

- **Thallus** of liverworts is flat or ribbon-like usually dichotomously branched.
- Some liverworts are attached to soil by **rhizoids** (*Marchantia*) others are falsely leafy (*Porella*).
- In liverworts **sex organs** develop on tip of thallus (*Porella*) or on special branches (*Marchantia*) which are antheridiophore and archegoniophore.

Bryopsida

- Archegonia and antheridia of mosses develop on different branches of same plants (*Funaria*) or on different plants (*Polytrichum*).
- In mosses, archegonia and antheridia form clusters and are mixed with sterile hair forming a structure called **paraphyses**.
- Spore of a moss, unlike of liverworts, develop into an alga-like structure called ***protonema***.
- Protonema produces a bud from which a haploid moss plant (gametophyte) is formed.

Anthoceropsida

- ***Antheridia* and *archegonia*** in hornworts are partially **sunken** in gametophyte.
- Sporophyte of hornworts is **advance** than that of liverworts and mosses.
- It is initially dependent on gametophyte then becomes independent.
- Sporophyte of anthocerotae has **stomata and chloroplast**.
- They also have a ***waxy cuticle*** to check excessive loss of water.
- In sporophyte of hornworts, at junction of foot and spore producing region, there is a band of **meristematic tissue.**
- It keeps on adding cells towards the spore producing region during the formation, maturation and dispersal of spores from the opposite end.
- Its fast growth rate results in increase in length of sporophyte for indefinite period of time

Tracheophyta

Tracheophytes are further subdivided into **four sub-divisions**.

- Psilopsida
- Lycopsida
- Sphenopsida
- Pteropsida

Features of Groups of Tracheophytes

Feature	Psilo	Lyco	Sphenop
Introduction	Psilophyta, earliest group	Club moss, spike moss (due to club/spike shaped strobili), ground pries	Horsetails, arthrophytes
Sporophyte	Diploid, dominant, rootless, rhizome with rhizoids, leafless	Diploid, dominant, differentiated root, stem & leaves	Diploid, dominant, differentiated root, stem & leaves
Gametophyte	Thalloid, colourless, underground, haploid, reduced, with mycorrhizal association	Haploid, reduced, underground	Thalloid, growing on clayed soil & mud
Examples	Fossils are *Rhynia*, *Horneophyton*, *Psilophyton*, *Cooksonia*. Living members are *Psilotum*, *Tmesipeteris*	*Lycopodium*, *Selaginella*	*Equisetum*

Psilopsida

Sporophyte (2n)

- **Stem** of sporophyte of psilopsids is differentiated into an **underground rhizome** and an **aerial part**, both are dichotomously branched.
- Aerial branches of psilopsid sporophyte are green, leafless and bear small veinless outgrowths.
- **Sporangia** are reproductive organ of psilopsida.
- **Internal structure of stem** is simple. Vascular tissue is narrow, central and solid without pith. Cortex is wide.

Gametophyte (n)

- It is thalloid, colourless and underground.
- It develops **mycorrhizal association** with a fungus. This symbiotic relation gives food to the gametophyte, while the fungus in return gets protection from it.

Lycopsids

They are also called:

- **Ground pries** because of their slight resemblance to evergreen plants.
- **Club mosses/ spike mosses** because of their club, spike shaped strobili and small leaves resembling mosses.

Spoprophyte (2n)

- Sporophyte of lycopsida differentiates into roots, stem and true leaves
- Leaves are **microphylls** i.e. small and single veined, arranged spirally or opposite.
- **Sporangia** develop singly on the upper side of sporophylls.
- Sporangia may be of one kind as in lycopodium or of two kinds i.e., microsporangia & megasporangia as in selaginella.
- Club shaped structure formed from clustering of sporophylls at the tips of branches are called **strobili**.
- Those sporophytes, which only produce one type of spores are called **homosporous**, while those producing spores of two types are called **heterosporous**, and this condition is called homospory and heterospory.
- Some lycopods like selaginella have a leaf-like structure called **ligule** (an outgrowth present on the upper side of the sporophylls near their base).

Gametophyte (n)

Their gametophyte is usually underground.

Lycopodium and Selaginella

Feature	Lycopodium	Selaginella
Sporangia	One kind	Two kinds i.e. microsporangia and megasporangia
Strobili (cone)	Absent	Present
Spores	One type (homosporous)	Two types i.e. microspores and megaspores, thus ***resembles*** seed producing plants (spermatophyte) because of its heterosporic conditions.
Ligule	No ligule	Ligule is present

Sphenopsida

They are also called **arthrophytes** because the whole plant body is composed of large number of joints.

Sporophyte (2n)

- Their **sporophyte** is differentiated into root, stem and leaves.
- **Leaves** are expanded or scale like, arranged in whorls.
- **Main stem** is not smooth instead it contains ridges and furrows.
- **Sporangia** are produced on sporangiophores and are aggregated to form **strobili.**

- Each **sporangiophore** has a slender stalk and an expanded disc at its free end. Sporangia appear on the underside of the disc.

Gametophyte (n)

It is a thalloid and grown upon clayey soil and on mud.

Pteropsida

This group is divided into **three classes** i.e. filicineae, gymnospermae and angiospermae.

Filicinae

- Plants present in class filicineae are called **ferns**.
- Ferns are seedless plants.
- Their leaves are called **fronds**.
- ***Circinate* vernation** is a pattern of development of fronds, such that when they are immature and young they are coiled.
- They are **worldwide in distribution,** abundant in tropics
- They are **shade and moisture loving plants.**
- Some are **epiphytic** (growing on bark of trees)
- ***Examples*** of ferns are *Dryopteris, Pteridium, Adiantum* and *Pteris*.

Gymnosperms

- These are ***heterosporous* plants** which produce seeds but no fruit
- They are **worldwide in distribution**, one of successful group of land plants, **1/3rd of total world's forest**.
- **'Gymno'** means 'naked' and **'spermae'** means 'seeded' so they are naked seeded plants.
- **Naked ovules** are born on exposed surfaces of megasporophylls, which unlike those of angiosperms are not enclosed in fruit but lie naked on the surface of fertile leaves.
- **Different genera** of gymnosperms are. Cycas (sago-palm), Pinus (pines), Taxus (yew), Picea (hemlock), Cedrus (deodar), Ginko etc.

Alternation of Generation

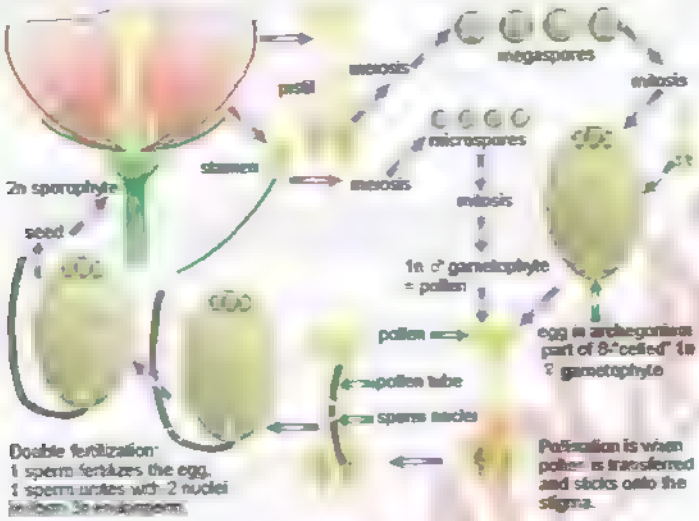
- They show **regular heteromorphic** alternation of generation
- Independent, dominant sporophyte and less conspicuous, dependent gametophyte is present.
- **Microsporophylls** produce microspores and **megasporophylls** produce megaspores.
- Female gametophytes always remain in ovule.
- The megasporophylls bearing ovules are not folded and joined at the margins to form an ovary for this reason seeds lie naked on the megasporophylls.

Angiosperms

- They are **heterosporous autotrophic plants** which produce flowers, fruits and seeds.
- **'Angio'** means **'close' and 'sperm'** means **'seed'.**
- Most abundant of land plants, **235,000 species** out of 360,000 plant species.
- A **flower** is a modified shoot, which consists of a pedicel, thalamus (torus) and floral leaves (sepals, petals, stamens and carpals.
- Thalamus, stamens and carpals are **modified leaves.**
- Sepals and petals are **non-essential** or non-reproductive parts.
- **Sepals** protect the inner parts.
- **Petals** attract insects for pollination.
- Sepals and petals fall off after pollination.
- Stamens and carpals are **essential** or reproductive parts of flower.
- **Stamen** consists of a filament and anther. It is male reproductive part of flower.
- **Carpal** consists of ovary (basal broader part), style and stigma (terminal part of style). It is female reproductive part of flower.

Alternation of Generation and Life Cycle

- Angiosperms exhibit **heteromorphic alternation of generation** in which dominant diploid sporophyte generation alternates with inconspicuous gametophyte generation.
- **Main plant** is **diploid sporophyte** differentiating into roots, stems and leaves at maturity flowers are also formed.



Seed Formation

- ***Testa*** **and** ***tegmen*** are coverings of seed that develop from integuments of the ovule
- ***Fruit*** is formed from the ovary wall.
- Seed under suitable conditions **germinates** and produces a seedling which gradually changes into sporophyte.

Classification of Angiosprems

On the basis of number of cotyledons in the embryo, angiosperms are divided into two classes i.e.

- Monocotyledonae (monocot)
- Dicotyledonae (dicot)

Monocot and Dicot

Different	Monocot	Dicot
Number of cotyledons	One cotyledon	Two cotyledon
Number of sepals and petals	3 or multiple of 3	4 or 5 or multiple of 4 or 5
Arrangement of vascular bundle in stem	Bundles scattered	Bundles in a ring
Pattern of veins	Parallel veins	Net veins
Presence or absence of wood	All herbaceous	Both herbaceous and woody
Symmetry of accessory parts of the flower	Both regular and irregular	Both regular and irregular
Individual or united petals	Both separate and gamopetalous	Both separate and gamopetalous
Relative position of male and female flower parts	Both superior and inferior ovaries	Both superior and inferior ovaries
Examples	Wheat, rice, maize	Gram, pea

TOPIC-9 » DIVERSITY AMONG ANIMALS

COURSE CONTENT

- Introduction, Grade Radiata, Bilateria
- Diploblastic and Triploblastic Organization
- Classification according to Coelom (Body Cavity)
- Protostomes and Deuterostomes
- Invertebrate and Vertebrate Phyla

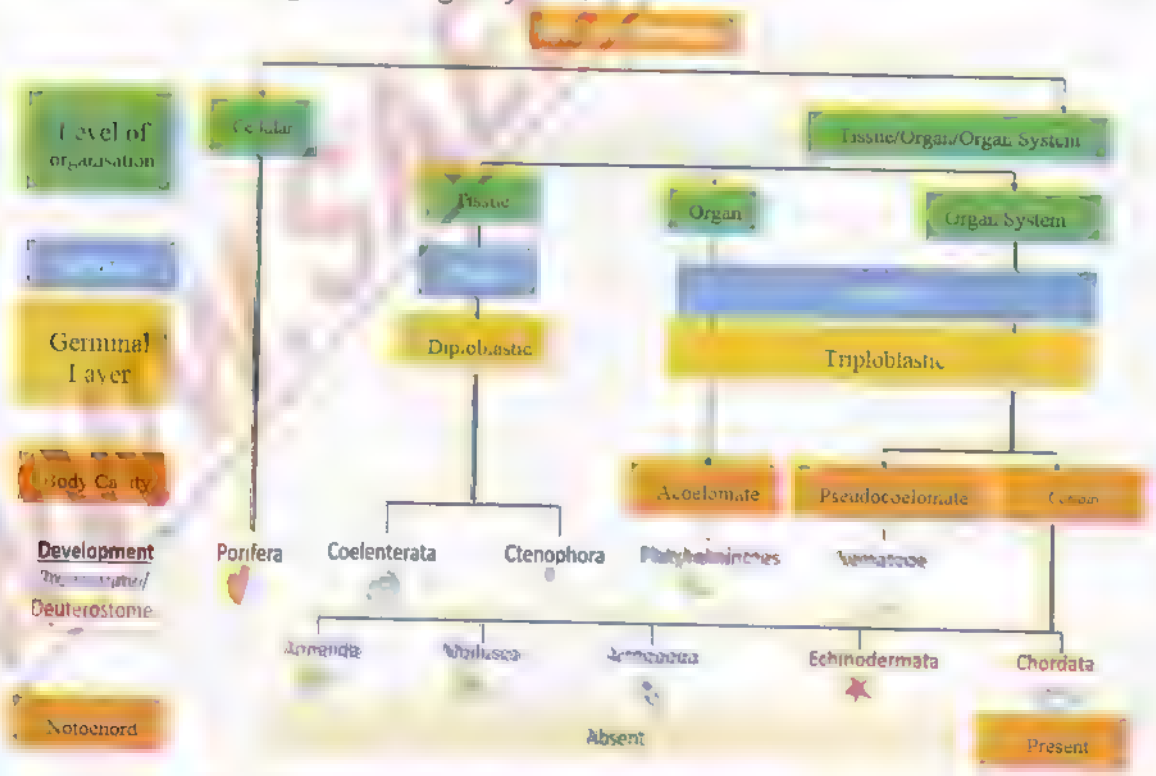
INTRODUCTION, GRADE RADIATA, BILATERIA

Kingdom Animalia

- The name Animalia is derived from Latin word anima meaning breath or soul.
- All the animals are multicellular heterotroph and usually acquire food by ingestion followed by digestion.

Complexity in Kingdom Animalia

- Simplest of the animals belong to subkingdom **Parazoa**. These animals lack tissues organized into organs and have indeterminate shape and are asymmetrical. Phylum porifera is included in parazoa.
- They have cellular grade of organization.
- The subkingdom **Eumatozoa** includes animals of other phyla which have symmetry and organization.
- In eumatozoa, similar cells are grouped together into a highly coordinated unit called tissue. The tissues are assembled into larger functional units called organs. Different organs operate together as organ system.



Classification on Base of Symmetry

Grade Radiata

- All the animals in grade radiata are diploblastic.
- It contains animals with radial symmetry.
- This is a condition or organization in which parts of the body are arranged around a central axis in such a way that any plane passing through the central axis divides the animal in halves that are almost mirror images of each other.
- Radial symmetry is considered an adaptation for a sessile life.
- Cnidarian (coelenterates) are placed in this group.
- The cylindrical body of a sea anemone can be cut in two equal halves vertically in any plane.

Grade Bilateria

- The animal can be divided into two equal parts by an imaginary line only in one plane.
- There have clearly defined right and left sides, anterior or head and posterior or tail ends and dorsal or back and ventral or front surfaces.
- The animals belonging to Phylum Platyhelminthes to Chordata are included in this group.
- Animals belonging to phylum Echinodermata have developed bilateral symmetry in their larva forms and adult echinoderms have secondarily developed radial symmetry, due to their special mode of life.
- All the animals included in grade bilateria are triploblastic.
- They may be acoelomate, pseudocoelomate and coelomate.

No symmetry (e.g. Porifera) | **Radial** symmetry (e.g. Cnidaria) | **Bilateral** symmetry (e.g. Arthropoda)

Diploblastic Organization

- Diploblastic animals belong to division ***radiata***.
- These animals have tissue level of organization.
- The body of these animals consists of two layers of cells, ***ectoderm*** and ***endoderm***.
- There is **jelly like mesenchyme** or **mesoglea** which in most cases is non-cellular.
- Diploblastic animals show lesser degree of specialization and they do not form specialized organs.
- There is no special transport system in these animals. Most substances are distributed within their body the by process of diffusion.
- There is no central nervous system in these animals. A neuron net is present.

- There is only one cavity in the body called **gastrovascular cavity** or **coelenteron** which has only mouth which serves for the entry of food and water and also for the removal of wastes along with water. This is known as **sac like digestive system.**
- They reproduce both asexually and sexually.
- Diploblastic animals are placed in phylum **Cnidaria.**

Triploblastic Organization

- These animals have **bilateral symmetry.**
- The body of these animals is made from three layers **ectoderm, mesoderm** and **endoderm.**
- After embryonic development these layers in most triploblastic animals are not distinct as separate layers of cells but are represented by the structures formed from them.
- The cells of these animals show greater degree of specialization. These have specialized organs and organ systems.
- The systems such as integumentary and nervous system develop from ectoderm.
- Mesoderm gives rise to muscular, skeletal and reproductive systems.
- Endoderm forms the lining of digestive tract and glands of digestive system such as liver.
- Triploblastic animals may be acoelomate, pseudocoelomate or coelomate

CLASSIFICATION ACCORDING TO COELOM (BODY CAVITY)

Acoelomates

- This group includes phylum **platyhelminthes.**
- There is **no body cavity** or **coelom.**
- Mesoderm forms a loose, cellular tissue **mesenchyma** or **parenchyma** which fills the space between the ectoderm and endoderm. It forms a packing around the internal organs of the animals to support and protect them.
- The gut is **sac-type** and there is no special transport system.
- Only excretory system is developed for the transport of excretory products. This system consists of **flame cells**, excretory ducts and excretory pores.
- Nervous system is well developed.

Pseudocoelomates

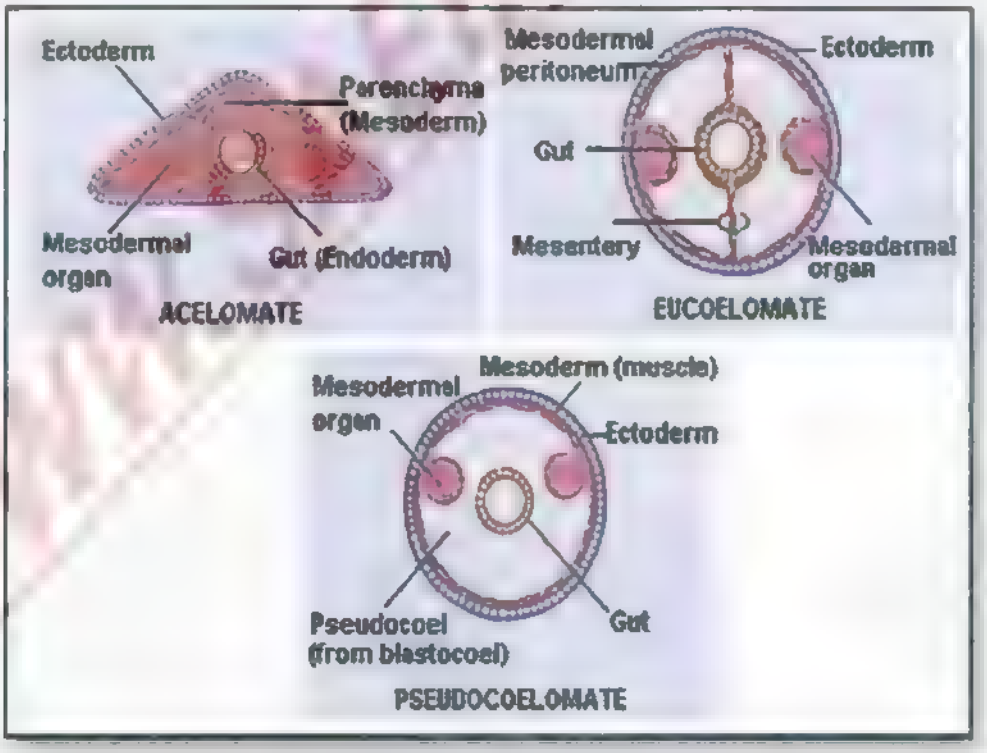
- This group includes phylum **aschelminthes.**
- The space between the body wall and the digestive tube is called **pseudocoelom** (false body cavity).
- Pseudocoelom is not homologous to true coelom because it is not lined by coelomic epithelium.
- It has no relation with the reproductive and excretory organs.
- It develops from the blastocoel of the embryo and is bound externally by the muscles and internally by the cuticle of intestine.

Coelomates

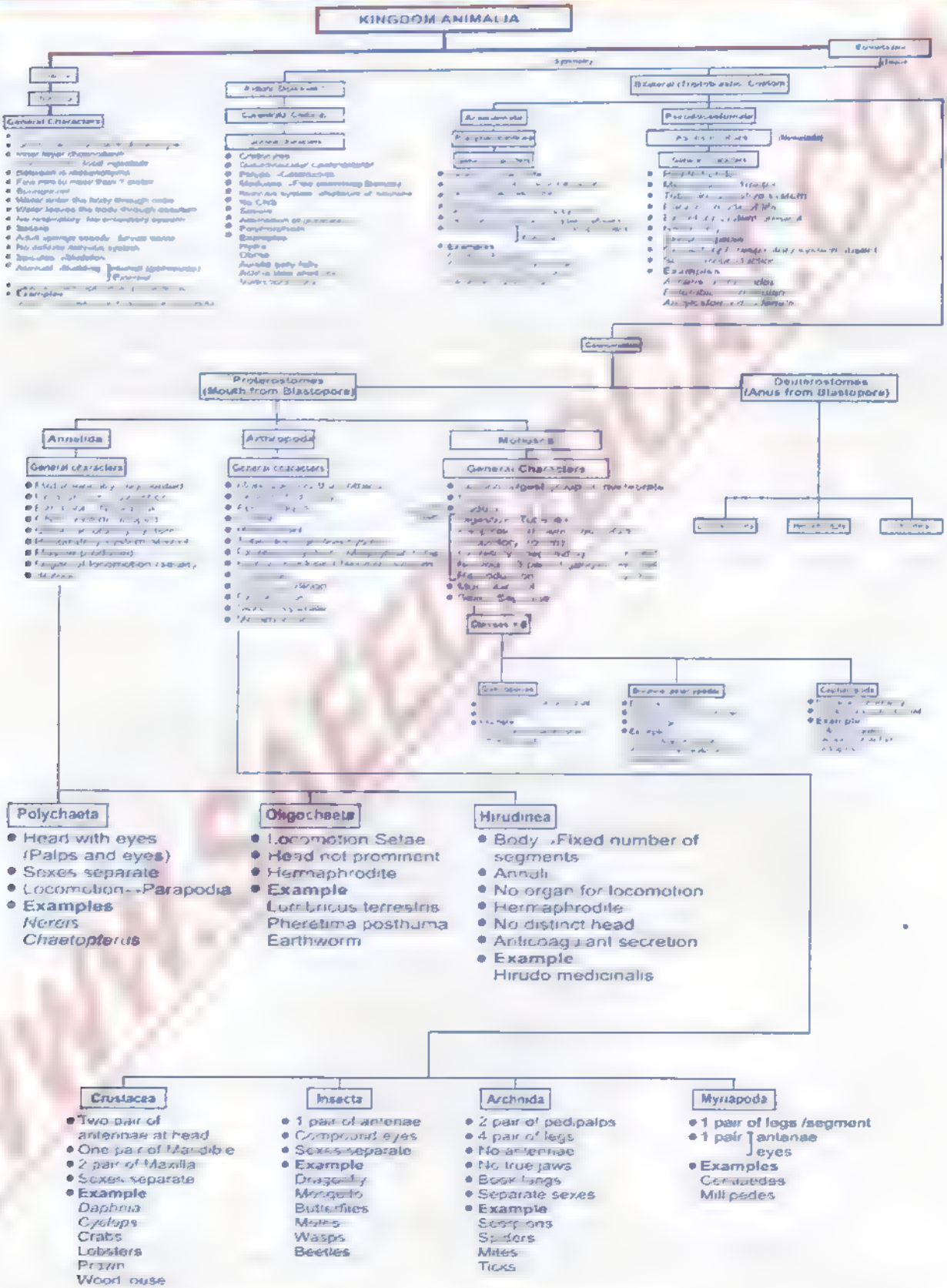
- **Coelom** is cavity present between the body wall and the alimentary canal and is lined by mesoderm.
- The mesoderm splits into outer parietal layer which underlines the body wall and the visceral layer which covers the alimentary canal and the cavity between them is the true coelom. It is filled with fluid called **coelomic fluid**.
- This group includes animals from **annelids** to **chordates**.
- In coelomates, gut includes more complexity and neuro-sensory system is well developed along with excretory system, circulatory system, respiratory and reproductive system.
- Coelomates are further divided into two groups proterostomia and deuterostomes.

PROTOSTOMES AND DEUTEROSTOMES

Cleavage is spiral and indeterminate.	Cleavage is radial and indeterminate.
Blastopore gives rise to mouth.	Blastopore forms anus.
Coelom is formed by splitting of mesoderm (Schizocoelous).	Coelom is developed from archenteron (Enterocoelous).
Mesoderm is derived from cells on anterior lip of blastopore.	Mesoderm is derived from wall of developing gut (archenteron).
It includes phylum annelida, Mollusca and arthropoda.	It includes phylum Echinodermata, hemichordate and chordata.



INVERTEBRATE AND VERTEBRATE PHYLA




Deuterostomes (Anus from Blastopore)
Examples
Examples
Acrania (Protochordata)
Urochordata
Cephalochordata
Examples
Examples
Examples
Examples
Example
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Examples

TOPIC-10 LIFE PROCESSES IN ANIMALS & PLANTS

TOPIC CONTENT

Nutrition

- Modes of Nutrition
- Mineral Nutrition in Plants with Deficiency Symptoms
- Carnivorous Plants
- Human Digestive System
- Digestion in Oral Cavity
- Digestion in Stomach
- Digestion in Small Intestine and Accessory Glands
- Digestion in Large Intestine
- Disorders of Digestive Tract

Gaseous Exchange

- Gaseous Exchange in Plants
- Role and Structure of Stomata
- Human Respiratory System
- Mechanism of Breathing
- Transport of Respiratory Gases and Respiratory Pigments
- Lung Capacities
- Respiratory Disorders

Transport

- Uptake and Transport of Minerals and Water
- Uptake of Water by Roots
- Water Potential
- Ascent of sap
- Transpiration and Factors Affecting it
- Translocation of Organic Solutes
- Blood Circulatory System (Blood)
- Structure of Human Heart
- Blood Vessels
- Blood Pressure and Rate of Blood Flow
- Lymphatic System
- Immune System

MODES OF NUTRITION

Organisms can be divided into two classes on the basis of their method of nutrition.

Autotrophic

- Autotrophic organisms can exist in an exclusively inorganic environment because they can manufacture their own organic compounds from the inorganic raw material taken from the surrounding media. This means that they produce their own sugars, lipids, proteins etc. from carbon dioxide, water and nitrates.

Heterotrophic

- Heterotrophic organisms are incapable of manufacturing organic compounds from simple inorganic nutrients and so they obtain organic molecules from the environment in the form of food.

MINERAL NUTRITION IN PLANTS WITH DEFICIENCY SYMPTOMS

- Generally, all autotrophic or photosynthetic organisms need carbon dioxide and water, which supply the carbon, oxygen and hydrogen. These are the predominant elements, the plant needs for the synthesis of organic molecules.

Minor Elements

There are many other elements that enter into the composition of plants. Some of these are;

- **Nitrogen**, which is part of proteins.
- **Phosphorous**, which is present in ATP, nucleic acid and many other compounds.
- **Magnesium**, which is part of chlorophyll.
- **Iron**, which is present in cytochromes.
- These are mainly obtained from soil. These are essential for growth and life of the plant. Crops fail to flourish, if grown repeatedly in the same field unless soil is replenished with these nutrients. The farmers replace these by spreading animal manure, sewage sludge or artificial fertilizers in measured quantities over the field. Some chemical fertilizers that are commonly used in Pakistan are urea, super phosphates, ammonium nitrate etc.

Mineral Element Deficiencies

It is very difficult or not possible to ascertain the effects of individual minerals in both plants and animals. However, the deficiencies of some elements cause serious diseases showing clear symptoms. For example:

- **Nitrogen deficiency** in soil results in **stunted growth** and **strong chlorosis** (lack of chlorophyll) particularly in old leaves.
- **Phosphorous deficiency** causes **stunted growth of roots.**
- **Potassium deficiency** causes leaf margins to become yellow and brown in colour and premature death of plant.
- **Magnesium deficiency** results in **chlorosis.**

Many economically important plant diseases due to mineral deficiency are now catalogued with the help of colour photography, enabling rapid diagnosis.

CARNIVOROUS PLANTS

There are a few that supplement their inorganic diet with organic compounds. These organic compounds are obtained by trapping and digesting insects and small animals. All of the insectivorous plants are true autotrophs, but when they capture prey, their growth becomes rapid. Apparently, nitrogenous compounds of animal body are of benefit to these plants. In some plants, the trapped insects are decomposed by bacteria. In others the trapped insects are digested by enzymes secreted by the leaves. The plants absorb the nitrogenous compounds thus formed.

Examples

- Pitcher plant (***Sarracenia pupurea***) has leaves modified into a sac or a **pitcher**, partly filled with water.

- The end of the leaf is modified to form a **hood**, which partly covers the open mouth of the pitcher.
- Small insects that fall into the pitcher are prevented from climbing out by numerous **stiff hairs**.
- The proteins of trapped insects are decomposed by **bacteria** or **enzymes** and the products of this decay are absorbed by the inner surface of the pitcher leaf.

Venous-Fly Trap

- In venous-fly trap (**Dionaea muscipula**), the **leaf is bilobed** with midrib between them.
- There is a row of long **stiff bristles** along the margins of each lobe.
- When an insect touches small sensitive hairs on the surface of the leaf, the lobes quickly come together with their bristles interlocked.
- The trapped insect is then digested by the enzymes secreted from the glands on the leaf surface and the products are then absorbed.

Sundew

Sundew (***Drosera intermedia***) shows another type of modification of leaf for insectivorous activity.

- The **tiny leaves** bear numerous **hair-like tentacles**, each with a gland at its tip.
- The insects, attracted by the plant's odour are entangled.
- Proteins of insects are digested by enzymes and the products are absorbed.

HUMAN DIGESTIVE SYSTEM

Digestion

- Process by which large, complex non-diffusible substances are converted into small, simple and diffusible forms is called digestion.
- Digestion that occurs with help of enzymes is called chemical digestion.
- Digestion that occurs without enzymes is called mechanical digestion e.g. mastication.
- Digestion that occurs inside the cell (food vacuole) is called intracellular digestion e.g. digestion in amoeba.
- Digestion that occurs outside the cell (in digestive cavity) is called extracellular digestion e.g. digestion in stomach.

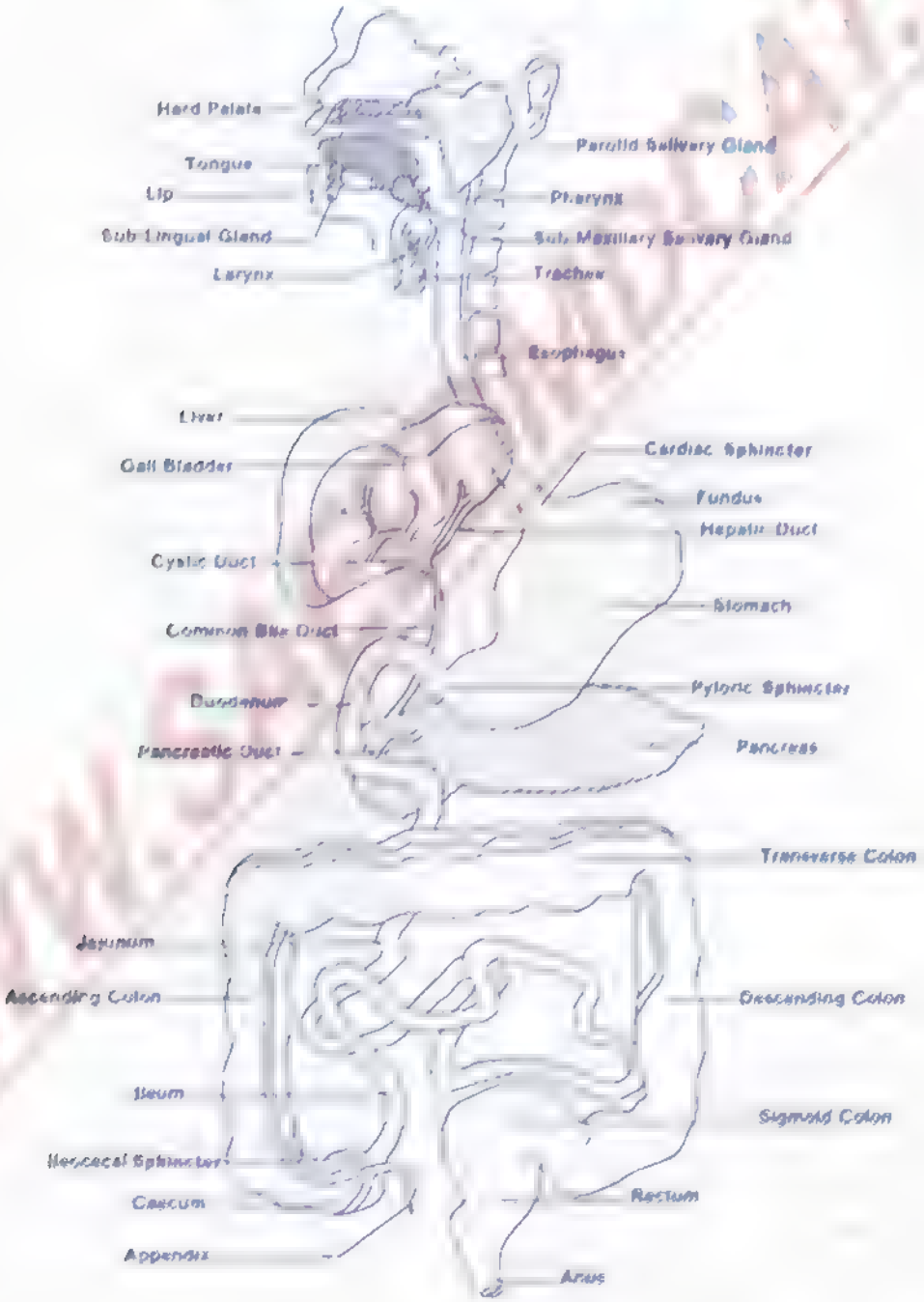
Human Digestive System

- Digestive system of a man consists of structures extending from mouth to anus (tube like)
- The main parts in the direction of passage of food are:
  Oral cavity → Oesophagus →Stomach →Small Intestine (Duodenum →Jejunum →Ileum) →Large Intestine (Caecum →Ascending Colon →Transverse Colon →Descending Colon → Sigmoid Colon → Rectum)
- **Alimentary canal** means the part of gut from oral cavity to anus. It is also called as **gastrointestinal tract** (GIT) or digestive tract.
- **Digestive system** means alimentary canal plus associated glands.

- Associated glands are salivary glands, liver and pancreas.
- Digestion occurs at three main sites:

Parts	Chemical Digestion	Mechanical Digestion
Oral Cavity	Amylase	Teeth
Stomach	Gastric Juice	Grinding
Small intestine	Pancreatic & Intestinal Juice	Emulsification

HUMAN DIGESTIVE SYSTEM



DIGESTION IN ORAL CAVITY

Oral Cavity

It is the site for entrance of food in alimentary canal.

Overall Functions of Oral Cavity

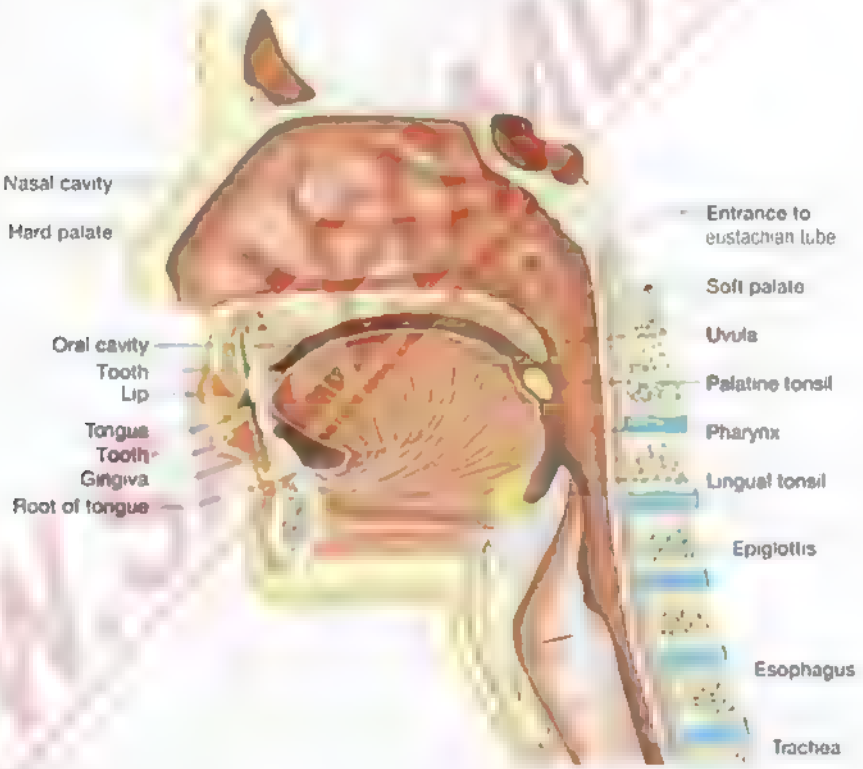
It performs four important functions:

- Selection of Food
- Grinding or Mastication
- Lubrication
- Digestion

Structures Associated with Oral Cavity

Oral cavity is bounded by:

- Palate
- Tongue
- Teeth
- Cheeks



Selection of Food

- When food enters in oral cavity, it is tasted, smelled and felt.
- Oral cavity is aided in selection by the senses of smell and sight.
- Tongue being sensory and muscular organ plays the most important role in the selection of food through its taste buds.

Grinding or Mastication

- Food is ground by means of molar teeth.
- This grinding is useful because:

- Oesophagus allows relatively small pieces to pass through.
- Small pieces have much more surface for enzymes to attack.

Lubrication & Digestion

These are main functions of oral cavity accomplished by saliva. Saliva is secreted by three pairs of salivary glands:

Salivary Glands

- Three pairs of salivary glands are:

Glands	Location	Secretions	Opening of Ducts
Parotid glands (Largest)	In front of ears	Saliva with amylase	Posterior part of oral cavity
Submandibular/ Sumaxillary glands	Behind jaws	Saliva with amylase & mucus	Floor of oral cavity
Sublingual glands (Smallest)	Below tongue	Saliva with mucus only	Floor of oral cavity

Saliva

- Fresh saliva is alkaline with pH nearly 8, quickly loses carbon dioxide and gets to pH 6.
- It has three major components:

Water and Mucus (GP)	Moisten and lubricate food
Sodium bicarbonate	Stabilizes pH and is slightly antiseptic
Salivary Amylase/ Ptyalin	Starch Glycogen → Maltose

End Result Bolus

- End result of digestion in mouth is small oval lump called ***bolus***.
- It is softened, partly digested slimy food mass

Anatomy of Oral Cavity	Physiology of Oral Cavity
Teeth	Mastication/ Mechanical digestion of food
Lips	Communication, Hold food in position
Jaws	Mastication/ Mechanical digestion of food
Tongue	Manipulation of food, hold food, Cleansing of teeth, Taste, Communication, Swallowing, mucus and serous
Soft Palate	Prevents entry of food in nasal cavity
Salivary Glands	Chemical digestion of food mainly carbohydrates
Hard Palate	Palatine bones, helps in grinding

Pharynx

- The pharynx is a cavity behind the mouth.
- It is common passage for digestive system and respiratory system.
- It is lined by mucus.

Swallowing

- Transfer of bolus from buccal cavity to pharynx and then to oesophagus is called **swallowing/ deglutition**.
- Beginning of swallowing is voluntary action and then it becomes involuntary. The swallowing procedure is regulated by nerves in the medulla oblongata and pons.

Events of Swallowing

(i) Tongue moves upwards and backwards against the roof of mouth, forcing the bolus to the back of the mouth cavity.

(ii) Soft palate is pushed up by tongue which closes nasal cavity.

(iii) Tongue forces the epiglottis (flap of cartilage) into more or less horizontal in position thus closing the opening of windpipe (glottis). Epiglottis diverts the bolus toward oesophagus.

(iv) The larynx (cartilage box round the top of windpipe) moves upward under the back of tongue.

(v) The glottis is partly closed by the contraction of ring of muscles.

Peristalsis

- **Peristalsis** is characteristic movement of digestive tract due to alternate contractions and relaxations of smooth muscles by which food is pushed along the digestive tract.
- It consists of the wave of contraction of circular and longitudinal muscles preceded by the wave of relaxation thus squeezing the food down along the canal.
- Relaxation of circular muscles in front of food is followed by a wave of strong contraction of circular muscles behind food.
- Peristalsis starts just behind the mass of food, from the buccal cavity, along the oesophagus to the stomach and then along the whole alimentary canal.
- **Antiperistalsis** are reverse peristaltic movements due to which food is passed from intestine back into stomach and even in mouth. It may lead to vomiting.
- Hunger contractions are peristaltic contractions caused by low blood glucose level. These create an uncomfortable sensation often called **hunger pangs**.
- Hunger pangs usually begin 12-24 hours after the previous meal.
- **Gravity** assist the movement of material through the oesophagus, especially when liquids are swallowed.

DIGESTION IN STOMACH

Introduction

- Stomach is an elastic muscular bag.
- Stomach is situated below the diaphragm on left side of abdominal cavity.
- It is typically J-shaped when empty.

Anatomy of Stomach

Parts

- First part of stomach where oesophagus empties its contents into stomach is called **cardiac region**.
- At the junction between esophagus and the stomach, there is a special ring of muscles called **cardiac sphincter.** It is also called as lower oesophageal sphincter. When the sphincter muscles contract, the entrance to the stomach closes and prevents backward movement of food. It opens when a wave of peristalsis coming down the esophagus reaches it.
- Point where stomach joins duodenum is called **pyloric sphincter**. Stomach empties into the duodenum through the relaxed pyloric sphincter.

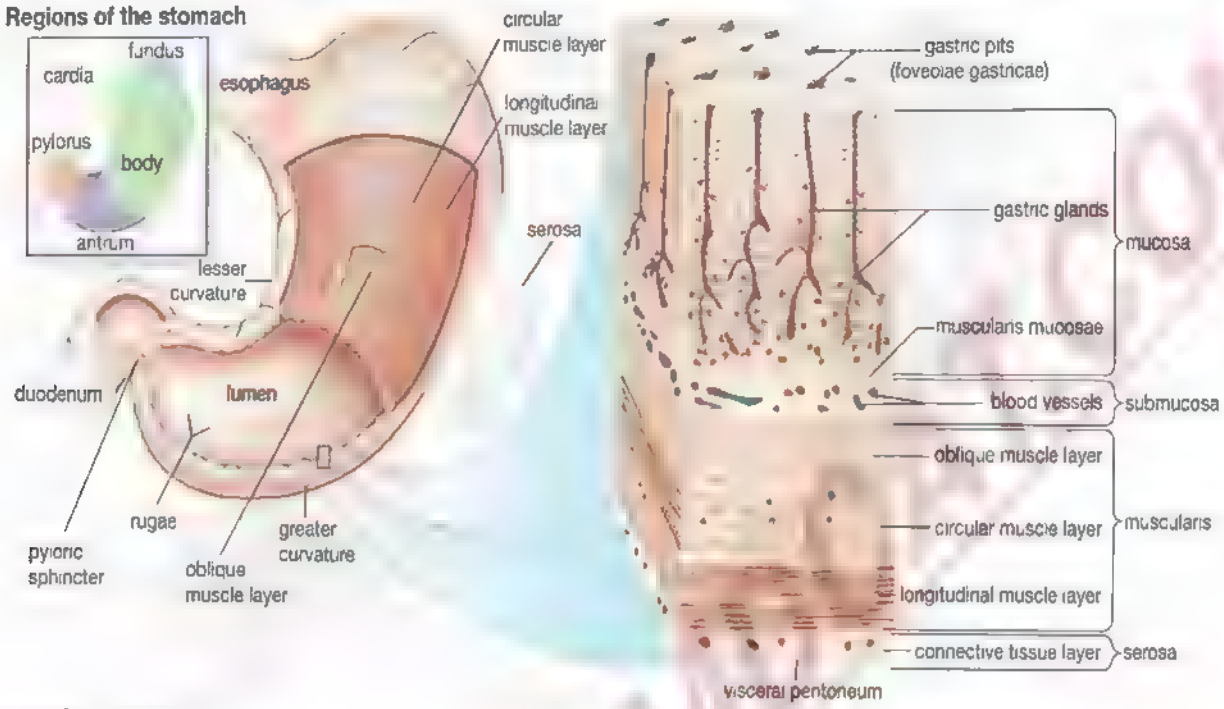
Layers

- Stomach wall is composed of three principal layers i.e.

(i) Outer layer of connective tissue called **serosa** or **adventitia**.

(ii) Middle layer of smooth muscles called **muscularis externa** along with submucosa. This muscular layer has innermost oblique muscles, middle circular and outer longitudinal muscles.

(iii) Inner layer (**mucosa**) of connective tissue with many glands.

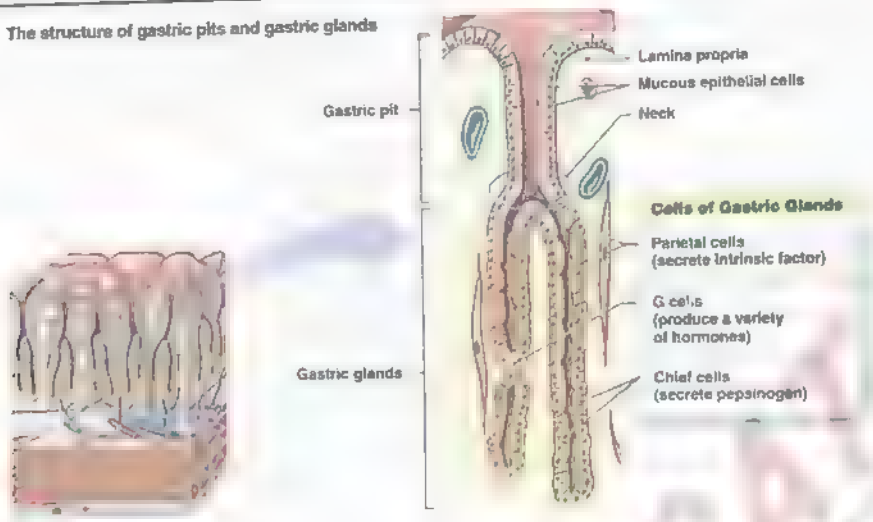


Gastric Glands

- Stomach has both **exocrine** and **endocrine glands**. Exocrine glands secrete gastric juice while endocrine secrete gastrin hormone.

Secretions		Functions
Mucous cells	Mucus	• Thick secretion • Covers inside of stomach • Protects stomach wall
Parietal/Oxyntic cells	HCl	• Maintains pH from 2-3 • Provide acidic medium for enzymes • Softens food & kills microorganisms • Converts inactive pepsinogen into pepsin • Inactivates salivary amylase • Low pH denatures many proteins
Zymogen/ Chief/ Principal cells	Pepsinogen	Hydrolyzes proteins into peptones and polypeptides.
G cells/ Endocrine cells	Gastrin	Stimulates gastric juice production, secretion& stomach motility

- Pepsinogen $\xrightarrow[\text{Pepsin}]{\text{HCl}}$ Pepsin
- Proteins $\xrightarrow{\text{Pepsin}}$ Polypeptides & Peptones



Regulation of Gastric Juice Production

- Both nervous and hormonal mechanisms regulate gastric secretions.
- Gastric juice secretion is regulated by small, sight and quality of food.
- Main hormones that regulate gastric secretions are gastrin and secretin.
- If more protein is present in food, it stimulates production of gastrin hormone from gastric endocrine lining of pyloric region of stomach
- More protein → More gastrin → More gastric juice

Physiology of Stomach

(i) Food Storage

- It stores food from meals for some time, making discontinuous feeding possible.

(ii) Digestion of Food

- It partly digests protein food.
- Stomach shows both chemical and mechanical digestion Mechanical digestion is carried out by middle muscular layer and is called **churning**. While chemical digestion is carried out by gastric glands.
- Muscular walls thoroughly mix up the food with gastric juice.
- End result of digestion in stomach is formation of semi-solid mass called **chyme** (semi solid.

(iii) Absorption

- Some absorption also occurs at stomach.

(iv) Defense/ Immunity

- Mucous membrane and HCl act as barriers against germs.

POINT TO PONDER

What is the chemical nature of gastrin and secretin?

DIGESTION IN SMALL INTESTINE AND ACCESSORY GLANDS

- It is the longest part of alimentary canal.
- There are three parts of small intestine i.e. duodenum, jejunum and ileum.
- Duodenum is first and the shortest part of small intestine and is about 20-25 cm long.

- Jejunum is second part with length of about 2.4 m ($2/5^{th}$ of small intestine)
- Ileum is the third and the longest part with length of 3.6 m ($3/5^{th}$ of small intestine).
- Small intestine has role to complete digestion and absorb digested products.

Duodenum

- Duodenum receives secretions from liver and pancreas.
- Duodenum also has its own secretions.
- It acts both as exocrine and endocrine gland.
- Exocrine function of duodenum is secretion of intestinal juice and endocrine function is release of secretin and small amount of gastrin hormone.
- ***Secretin*** is hormone produced by the action of acidic food on internal mucosa of duodenum. It inhibits production of gastric secretions and promotes production of secretions of liver and pancreas.
- Chyme after neutralization by secretions from liver, pancreas and duodenum is called **chyle** (liquid).

Pancreas

- Pancreas is also a large **dual gland**.
- Pancreatic juice is produced by exocrine part of pancreas, which is poured in duodenum by pancreatic duct.
- Endocrine part of pancreas produces hormones insulin and glucagon.

Components of Pancreatic Juice

Component	
Amylase (amylopsin)	Carbohydrate digesting enzyme(Starch Glycogen → Maltose)
Lipase	Fat digesting enzyme(Fats → Fatty acids + Glycerol)
Trypsin	Protein digesting enzyme(Proteins → Polypeptides + Peptones)
Chymotrypsin	Protein digesting enzyme(Proteins → Polypeptides + Peptones)
Sodium bicarbonate	Neutralizes chyme, provides alkaline medium

- Trypsin is secreted as inactive trypsinogen, which is activated by enterokinase, an enzyme secreted by the lining of duodenum.
- Chymotrypsin is secreted as inactive chymotrypsinogen, which is activated by trypsin.

Liver

- Bile is produced in liver, stored in gall bladder, acts in small intestine.
- Bile is transported from liver to gall bladder then to small intestine through bile duct.
- Bile is green, watery fluid containing salts and **no enzyme**.
- Green colour of bile is due to bile pigments produced due to breakdown of hemoglobin.
- Bile salts emulsify fats i.e. converts it into small globules.
- These small globules are easily digested by water soluble lipase.
- Accumulation of bile pigments in blood causes **jaundice**.
- Cholesterol secreted by liver may

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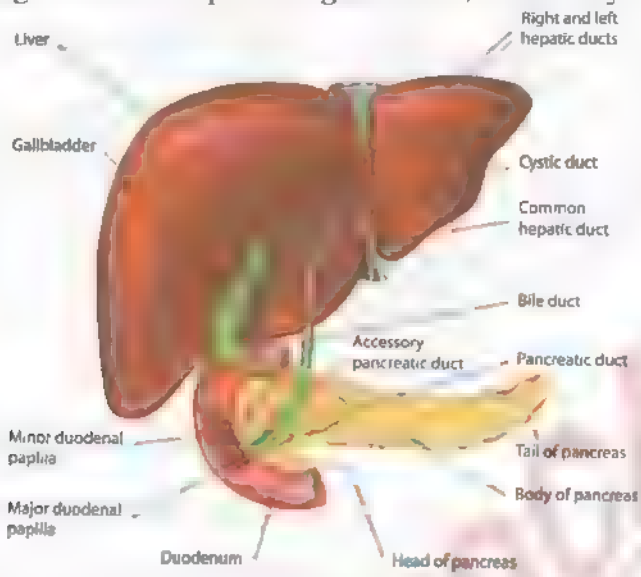
precipitate in the gall bladder to produce **gall stones**, which may block the release of bile.



Jejunum and Ileum

- Jejunum and ileum are involved in complete digestion of food.

Enzymes of Intestinal Lining

Enzyme	Substrate	Product
Amino peptidase	Polypeptides	Dipeptides
Erypsin	Dipeptides	Amino acids
Lipase	Fats	Fatty acids & glycerol
Maltase	Maltose	Glucose
Lactase	Lactose	Glucose & galactose

Absorption of Food

- Internal surface of ileum has many folds, which exhibits velvety appearance due to the presence of numerous finger-like outgrowths called **villi**.
- Each villus has outer covering of epithelial cells, blood capillaries and **lacteals**.
- Epithelial cells of villi have countless, closely packed cylindrical processes, **microvilli**.
- The total area of absorption becomes incredibly large due to the infoldings, villi and microvilli.
- The end products of starch and glycogen, which is glucose, and the end product of proteins (amino acids) are absorbed into blood capillaries of villi by diffusion or active transport Some of the fatty acids and glycerol (end products of lipid breakdown) are also absorbed into blood stream.
- A large proportion of fatty acids and glycerol enter the epithelial cells of villi, where they recombine into fats. These fats along with proteins enter into the lacteals and are transported in form of lipoproteins droplets (**chylomicrons**) through lymph vessels. These pass into blood stream via thoracic lymph duct. The lipoproteins are hydrolyzed by blood plasma enzyme and enter body cells, where they may be used in respiration or stored as fat in the liver, muscles or under the skin.

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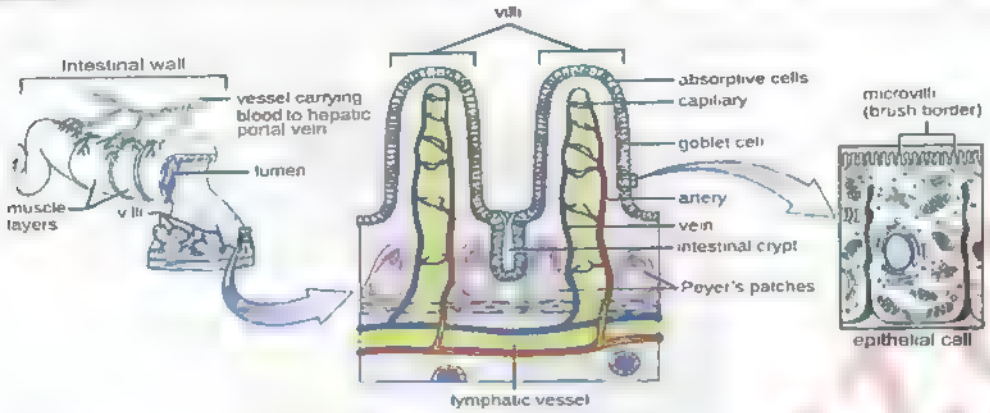


End Result

- After absorption, the intestinal contents are pushed along the alimentary canal by normal peristaltic activity.
- At the end of ileum, there is an **ileocolic/ileocecal sphincter** that transfers residues to large intestine.

DIGESTION IN LARGE INTESTINE

- Large intestine is last part of alimentary canal.
- It is divided into caecum, colon and rectum.

Caecum

- **Caecum** is a blind sac that projects from the large intestine between ileum and colon.
- Finger-like appendix arises from the blind end of caecum. Inflammation of appendix is called **appendicitis**.

Colon

POINT TO PONDER

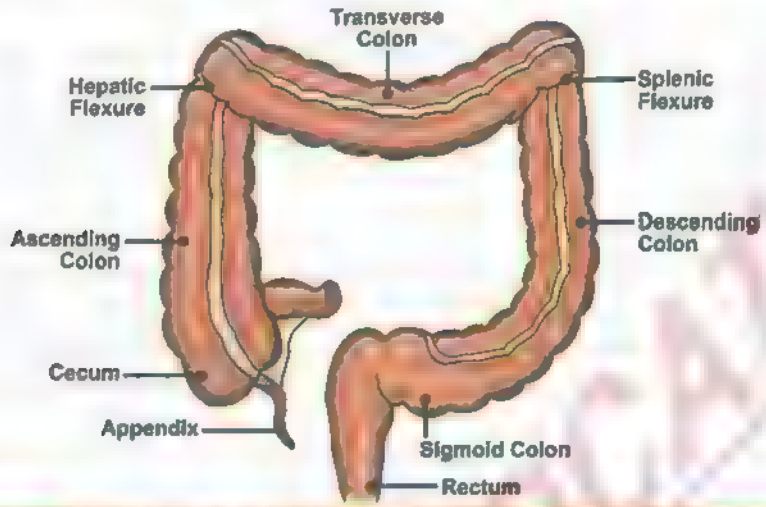
- **Colon** is longest part of large intestine. It is further divided into ascending, transverse, descending and sigmoid colon.
- The material that pass from small intestine to large intestine contain a large amount of water, dissolved salts and undigested material.
- Large intestine is involved in absorption of water and salts while undigested material is rejected as feces.
- The fecal matter contains a large number of bacteria, plant fibers, sloughed off mucosal cells, mucus, cholesterol, bile pigments and water.
- Less absorption leads to **diarrhea** and then dehydration. If this condition is unchecked, it leads to dehydration and even death. Excessive absorption of water leads to **constipation**.
- Large intestine also harbors a large population of useful bacteria (mutualistic relation) that synthesize some vitamins especially vitamin K, which are absorbed in blood.

Rectum

POINT TO PONDER

- It is the last part of large intestine where feces are temporarily stored and rejected through anus at intervals.
- Anus is surrounded by two sphincters. The internal anal sphincter is of smooth muscles and outer anal sphincter is of striped muscles.

- **Defecation reflex** is involved in emptying of rectum from feces. It is generated when rectum is filled with feces. It is consciously controlled in individuals other than infants.



DISORDERS OF DIGESTIVE TRACT

Dyspepsia

Incomplete or imperfect digestion is called dyspepsia. This is not a disease in itself but symptomatic of other disorders or diseases.

Symptoms

This is characterized by;

- Abdominal Discomfort
- Flatulence
- Heartburn
- Nausea
- Vomiting

These symptoms may occur irregularly and in different pattern from time to time.

Causes

Dyspepsia may occur due to;

- **Acidity** in stomach
- **Faulty function** of stomach and intestine
- **Insufficient** quality or quantity of **bile secretions**

Food poisoning

It is an illness from indigestion of food containing toxic substances.

Symptoms

The symptoms of food poisoning are

- Diarrhea
- Vomiting
- Abdominal pain

These symptoms usually occur from 12-24 hours after eating contaminated food.

Causes

One of the commonest causes of food poisoning are the toxins produced by bacteria, **Salmonella** and **Campylobacter**.

These bacteria live in the intestines of cattle, chicken and duck without causing symptoms there. If humans drink milk or eat meat or egg of such infected animals, they develop food poisoning.

Infection is most likely if **unpasteurized milk** is drunk or if meat is not properly cooked.

Treatment

The liquid that escapes during defrosting frozen meat contains Salmonella bacteria. The dishes and utensils, while the meat is defrosting, must not be allowed to come in contact with any other food.

Botulism

A severe form of food poisoning is called botulism. It is caused by toxins of **Clostridium botulinum**. These toxins have selective action on central nervous system causing fatigue, dizziness, double vision, headache, nausea, vomiting, diarrhea and abdominal pain.

- It usually develops from improperly canned or otherwise preserved foods.

Obesity

It is the term employed when a person has abnormal amount of fat on the body and a person with this condition is called obese.

Causes

- It is mainly due to overeating and eating fatty food.
- Hormonal causes may also consider being involved. Best example is that some people eat very less fat but become fatty. On the other hand, some eat too much fat but do not become fatty.

Mechanism

- Certain cells accumulate fat drops in cytoplasm. As these drops increase in size and number, they join together to form one large fat globule in the middle of the cell, pushing cytoplasm into thin layer and nucleus to one side. Groups of fat cells join to form **adipose tissue**.

Adipose tissue usually develops in the abdomen around the kidneys and under the skin.

Complications

An obese person is much more likely to suffer from;

- High blood pressure
- Heart diseases
- Diabetes mellitus
- Stomach disorders

Control

- Obesity can be controlled by reducing fatty food, by eating balanced food. In case of hormonal disturbance, hormonal therapy can be used.

Anorexia Nervosa

This term is employed to the **loss of appetite** due to the fear of becoming obese.

Such feelings develop in human females between the ages of **12-21 years.**

Causes

- It usually affects girls after onset of puberty. It is characterized by loss of appetite due to fear of becoming obese. Such girls are often immature and are unable to cope with the challenges of puberty and emerging sexuality.

Treatment

- **Psychiatric therapy** is required to treat anorexic girls.

- Patient is often **fed through any route** other than alimentary canal, which may be intramuscularly or intravenously.
- Recovery is very slow and it may take 2-4 years and in some cases longer.

Bulimia Nervosa

It is **neurotic disorder** in slightly older girls. It is characterized by bouts of overeating fattening food such as fried food or cream cakes.

Symptoms

Too much eating is usually followed by;

- Self-induced vomiting
- Fasting
- Purgatives

Complications

The frequent vomiting and purging may cause physical effect including;

- Serum electrolyte imbalance
- Recurring infection

Treatment

Treatment is likely to be prolonged. Initially treatment is to overcome the effects of weight loss and malnutrition. Treatment should be in hospital under strict supervision.

Piles

Piles or **hemorrhoids** are masses of dilated, tortuous veins in the anorectal mucosa.

Symptoms

- Sometimes, these masses start **bleeding** during bowel movement.
- Situation may aggravate when the patient suffers from **constipation.**
- The urge to defecate is depressed and it becomes difficult to expel feces.

Complications

Physical distention of rectum may cause other symptoms of ill health.

Treatment

- The only therapy required is **improvement of hygiene** and use of food softeners such as roughage in food or laxatives.
- Patients are advised not to sit on hard seats.
- Hemorrhoids are removed **surgically** in some cases.

Ulcer

- Sore produced by eating away of the walls of the stomach or duodenum after break down of mucous layer due to digestive enzymes is called ulcer.

Causes

- Excess gastric acid secretion is an important factor of peptic ulcer.

Complications

- Sometimes a hole develops in the wall of the digestive tract and the contents of the tract spill into the abdominal cavity, leading to severe infections, which may prove to be fatal, if immediate medical care is not sought.

Care

- Smoking, spicy food, alcoholic beverages, coffee, tea and stress should be avoided by the patients suffering from ulcer.

GASEOUS EXCHANGE IN PLANTS

- Plants like animals also get their energy from respiration.
- In plants, in contrast to animals, no special organ or system is present for gaseous exchange as they exist in higher animals.
- Every cell of plant carries out exchange of gases according to its needs.

- The transport system of plants which includes conducting tissues i.e. xylem and phloem is not involved in the transport of gases in the plants.
- In most cells of mesophyll which are specialized for photosynthesis, there are present large air spaces.
- These air spaces are directly involved in gaseous exchange.

ROLE AND STRUCTURE OF STOMATA

- Stomata are the main sites of exchange of gases in plants.
- Stomata are largely present in the leaves and in young stem.
- In older stems, cork tissue is present which is formed of dead cells.
- The cork tissue has special pores called lenticels which are involved in gaseous exchange.
- Land plants get their oxygen directly from air which enters through stomata.
- Enormous number of stomata is present on the leaves.
- It is estimated that there are **12000 stomata per square centimeter of leaf surface in Tobacco plant** These stomata lead to the intercellular spaces (spaces between cells) of mesophyll tissue, the air spaces are comparable to honey comb.
- These air spaces may comprise up to **40% of the total volume of the leaf.** The exchange of gases between and the moist surface of mesophyll cells take place promptly. The roots of the land plants get their oxygen form the air existing in the spaces between the soil particles.
- Aquatic plants obtain their oxygen by diffusion from dissolved oxygen in water.

HUMAN RESPIRATORY SYSTEM

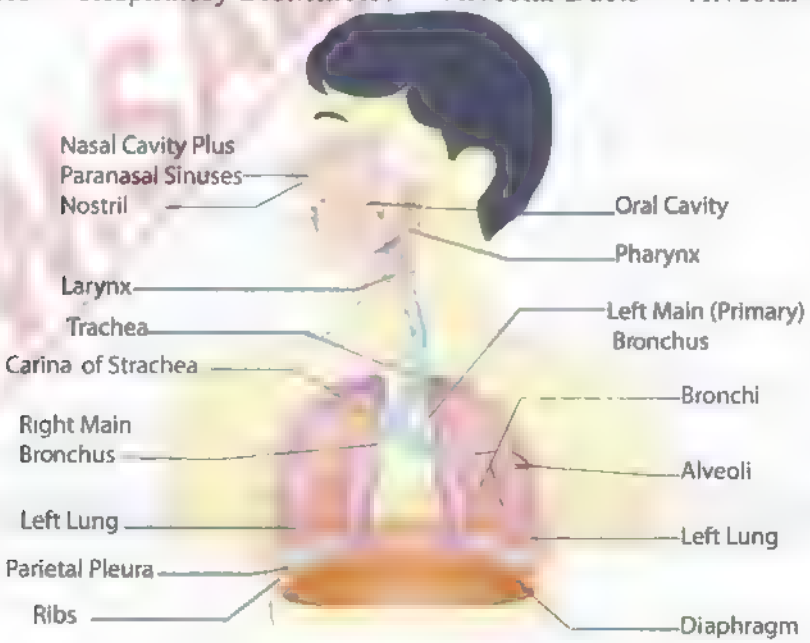
Human respiratory system includes:

(i) Air Passageway

(ii) Lungs

Air Passage Way

- It is passage way by which air enters or leaves the lungs.
- It consists of following components in sequence:
  Nostrils → Nasal Cavities → Pharynx → Larynx → Trachea → Bronchi → Terminal Bronchioles → Respiratory Bronchioles → Alveolar Ducts → Alveolar Sacs



Components	Anatomy	Physiology
Nostrils (2)	• Bone and cartilage • Hair • Mucous membrane	• Filtration of larger particles. • Moistening • Warming
Nasal Cavities (2)	• Each cavity subdivided into 3 passage ways. • Ciliated epithelium • Mucous membrane	• Filtration • Moistening • Warming.
Pharynx/ Throat	• Muscular passage • Mucous membrane	• Channelizes air to larynx
Larynx/ Voice box	• Cartilaginous box • Glottis • Epiglottis • Vocal cords	• Air passage way • Voice production
Trachea/ Windpipe (1) (ventral to oesophagus)	• C-shaped cartilage rings • Ciliated epithelium • Mucous cells/ Goblet cells	• Air passage way • Filtration • Moistening
Primary Bronchi (2)	• C-shaped cartilage rings • Ciliated epithelium • Mucous cells	• Air passage way • Filtration • Moistening
Secondary & Tertiary Bronchi	• Irregular cartilage plates • Ciliated epithelium • Mucous cells	• Air passage way • Filtration • Moistening
Terminal Bronchioles	• Diameter of 1 mm or less • No cartilage • Ciliated epithelium • Mucous cells	• Air passage way • Filtration • Moistening
Respiratory Bronchioles	• No cartilage • No Ciliated epithelium • Mucous cells	Gaseous exchange with blood
Alveolar Ducts& Alveolar Sacs	• Single layered surrounded by blood capillaries • Lined by surfactant	Gaseous exchange with blood

POINT TO PONDER

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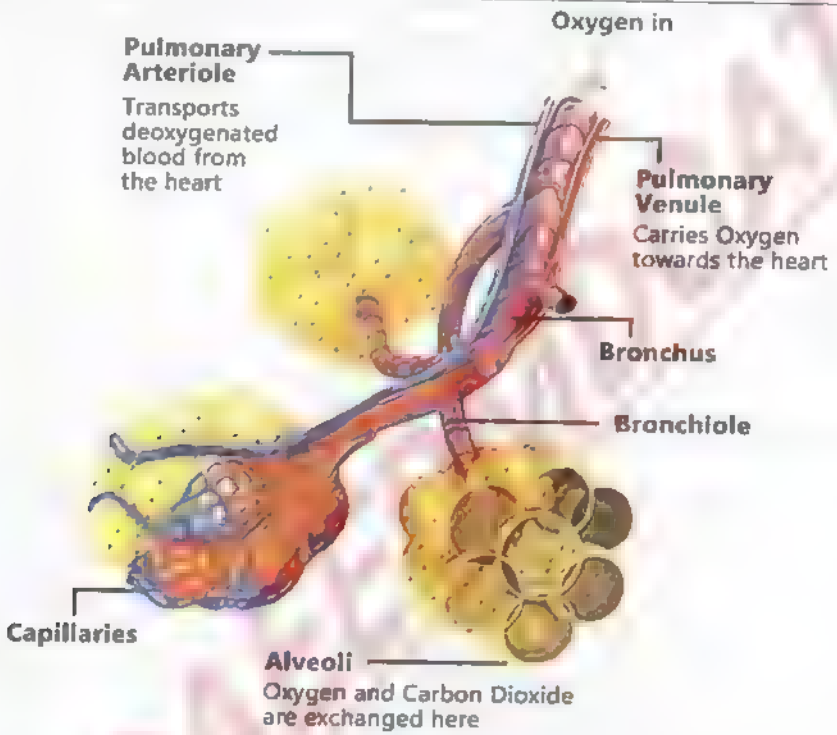
- Epiglottis is cartilaginous lid having a muscularly controlled, hinge-like action.
- Vocal cords are two thin edged stretched fibrous bands. These are larger in male so male have low pitched voice.
- Cartilage in air passage way prevents collapse.
- Bronchioles are made up of mainly circular smooth muscles. Change in diameter is possible through bronchioles.

- Air sac is the functional unit of lungs

Components	Cartilage	Ciliated epithelium with goblet cells	Smooth muscle	Elastic fibers
Trachea	✓	✓	✓	✓
Bronchi	✓	✓	✓	✓
Terminal Bronchiole	×	✓	✓	✓
Respiratory Bronchiole	×	×	✓	✓
Alveolar Duct	×	×	✓	✓
Alveolar Sac	×	×	✓	✓



Lungs

- They are closed sacs that are connected to the outside by the way of trachea and nostrils or mouth.
- The right and left lungs are slightly unequal in size.
- Lungs are spongy because of presence of millions of alveoli.
- Lungs are placed in the chest cavity.
- Chest cavity is bounded by ribs and inter-costal muscles on the sides.
- The floor of the chest is called diaphragm. Diaphragm is a sheet of skeletal muscles.
- Lungs are covered by a double layered thin membranous sac called ***pleura***.

POINT TO PONDER

Surfactant

- Mixture of lipoproteins secreted by alveolar epithelium.
- Forms a layer over the surface of the fluid within the alveoli to reduce surface tension.
- In premature infants, respiratory distress syndrome is common due to its deficiency.

MECHANISM OF BREATHING

- Breathing is a process by which fresh air containing oxygen is pumped into the lungs and air with more carbon dioxide is pumped out of lungs.
- It has both voluntary and involuntary control.
- It is a mechanical process consisting of two phases, inspiration and expiration.
- During rest, normal breathing rate is **15-20 breaths/min** in humans and it can increase to 30/min during exercise.

Phases of Breathing

	Inspiration	Expiration
Another Name	Inhalation	Exhalation
Basic Mechanism	Passive expansion of lungs	Passive contraction of lungs
Nature	Active process involving muscle contraction	Passive process involving elastic recoil
Definition	Taking in of air into the lungs	Removal of air low in O_2 and high in CO_2 from lungs outside body
Diaphragm	Contracts Moves down Becomes less dome-like	Relaxes Moves up Become more dome-like
Rib Muscles	Contract	Relax
Rib cage	Moves upward, forward & outward	Moves downward, inward& backward
Overall Change in Volume	Increases	Decreases
Changes in Pressure	Decreases	Increases
Air Moves	Into lungs	Out of lungs

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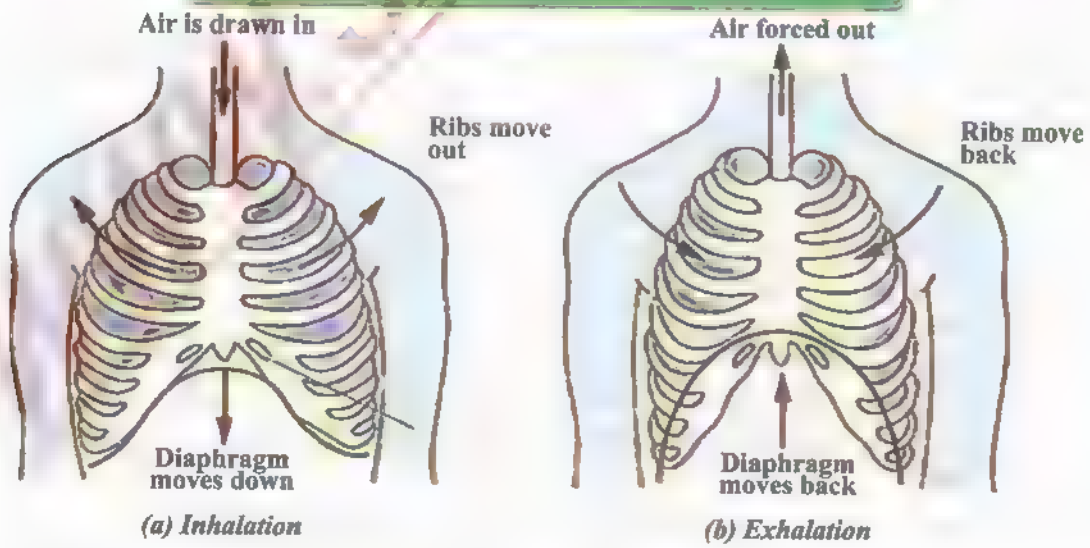
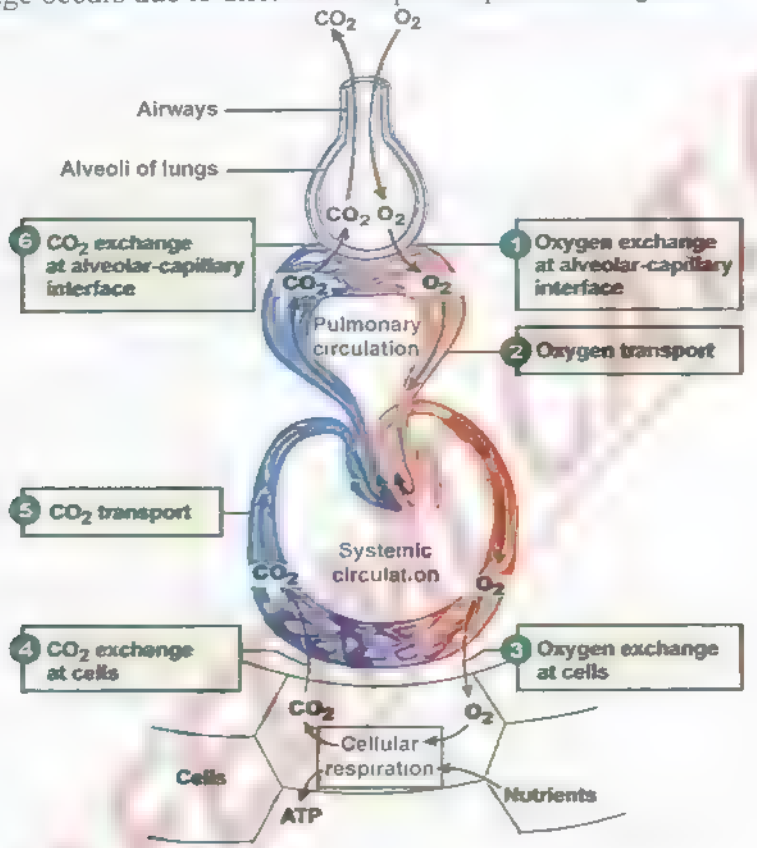


TRANSPORT OF RESPIRATORY GASES IN HUMANS AND PLANTS

- Gaseous exchange follows principles of **diffusion.**
- This exchange occurs due to difference in partial pressure of gases.



Transport of Oxygen

- Most of the oxygen is transported ***through haemoglobin.***
- A small proportion is transported through plasma in dissolved form.
- Haemoglobin acts as an efficient oxygen carrier.

At Lungs

- Haemoglobin readily combines with oxygen to form bright red oxyhaemoglobin.
- $Hb + O_2 \rightarrow HbO_2$
- ***Maximum capacity*** of haemoglobin to carry oxygen is about **20ml/100ml** of blood at sea level. At this blood will be 100% saturated.
- Under normal conditions, blood of alveoli of lungs is not completely oxygenated.
- ***At 115 mmHg*** oxygen tension, there is **19.6ml of O_2/100ml** of blood, where Hb is **98% saturated.**

At Aerobic Tissue

- Oxyhaemoglobin is unstable and splits into the normal purple red haemoglobin and oxygen in the condition of low oxygen concentration and low pressure.
- An enzyme, called **carbonic anhydrase,** present in RBC facilitates this activity.
- $HbO_2 \xrightarrow{\text{Carbonic Anhydrase}} Hb + O_2$
- ***Oxyhaemoglobin*** is unstable at pressure below 60 mmHg.

- Every 100ml of blood gives **5ml O_2 to aerobic tissue.**

Factors Affecting O_2 Holding Capacity of Hemoglobin

1. Carbon Dioxide

- When carbon dioxide pressure increases, the oxygen tension decreases, the capacity to hold oxygen becomes less.
- Increased carbon dioxide tension favours the greater liberation of oxygen from the blood to the tissue.

2. Temperature

- Rise in temperature causes a decrease in oxygen carrying capacity of blood.
- For example, in increased muscular activity.

3. pH

- With decrease in pH of blood, amount of oxygen bound to haemoglobin also declines.
- Decreased pH results from increase in hydrogen ions. Hydrogen ions combine with the protein part of hemoglobin molecules causing a decrease in its ability to bind oxygen.

Transport of Carbon Dioxide

- Carbon dioxide is more soluble than oxygen.
- CO_2 produced in Cell → Dissolved in Tissue Fluid → Passes to Plasma of Blood
- CO_2 is much more important than oxygen as a regulator of normal alveolar ventilation (breathing).

Ways of Transport of CO_2

20%	Carboxyhemoglobin/ Carbaminohaemoglobin
5%	Plasma proteins
70%	Bicarbonate ions combined with sodium in plasma.
Small Amount	By corpuscles combined with potassium

- Carboxyhaemoglobin/Carbaminohaemoglobin is formed when carbon dioxide combines with amino terminal of globin chains of haemoglobin.

Transport as Bicarbonate Ions

At Aerobic Tissue

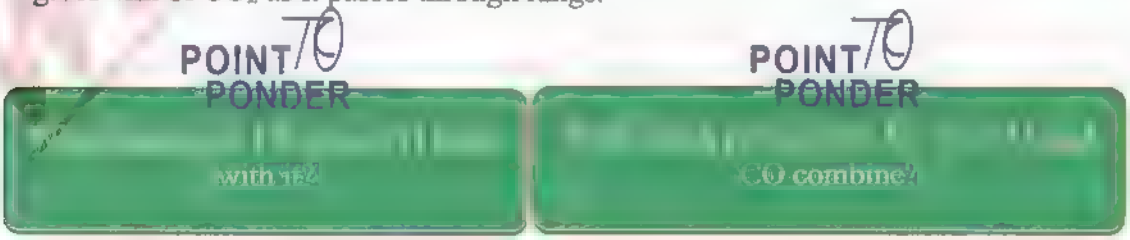
- $CO_2 + H_2O \xrightarrow{\text{Carbonic Anhydrase}} H_2CO_3$
- $H_2CO_3 \rightarrow H^+ + HCO_3^-$

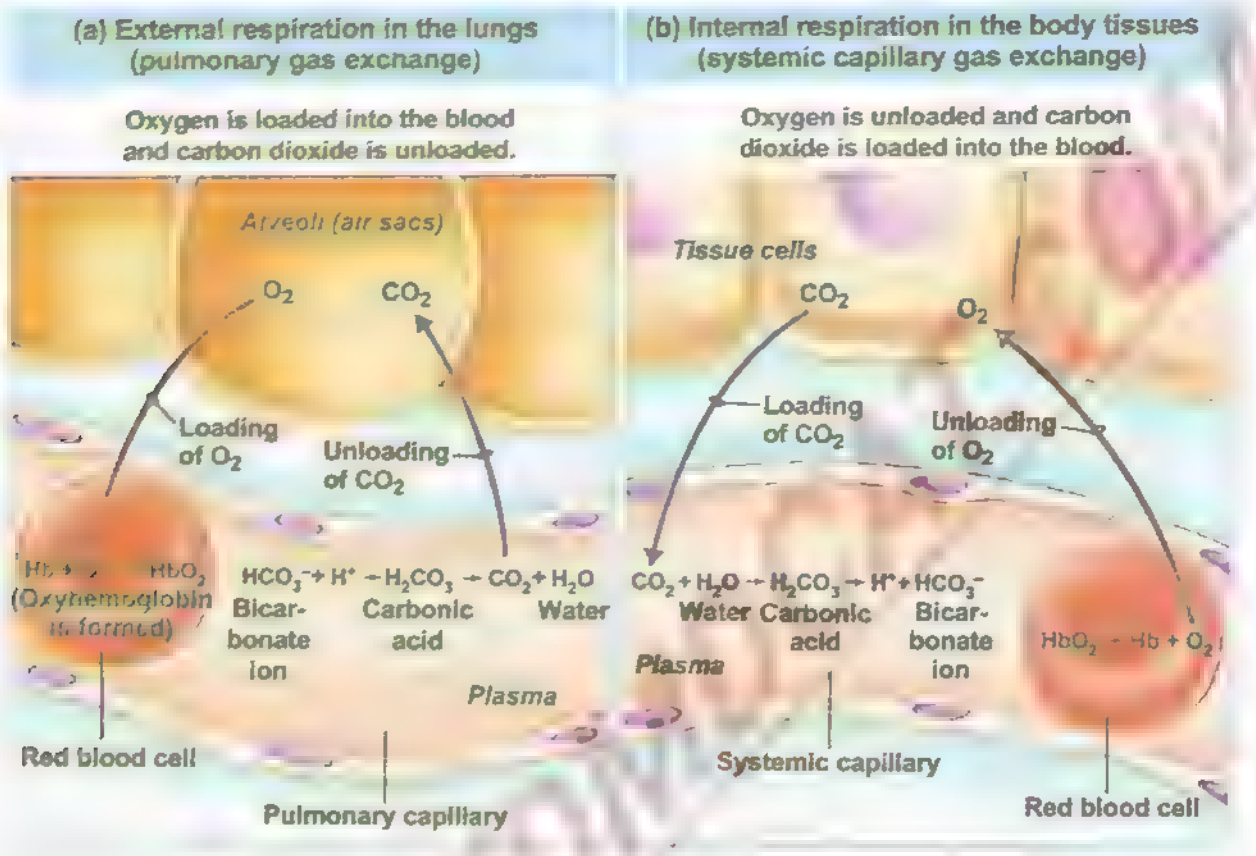
At Lungs

- $HCO_3^- + H^+ \rightarrow H_2CO_3$
- $H_2CO_3 \xrightarrow{\text{Carbonic Anhydrase}} CO_2 + H_2O$

Capacity of Blood for CO_2

- ***Arterial blood*** contains about ***50ml of CO_2/100ml*** of blood.
- ***Venous blood*** contains ***54ml of CO_2/100ml*** of blood.
- Each 100ml of blood takes 4ml of carbon dioxide as it passes through the tissues and gives 4ml of CO_2 as it passes through lungs.





Role of Respiratory Pigments

- Two respiratory pigments are important in humans i.e. haemoglobin and myoglobin.
- **Hemoglobin** increases oxygen carrying capacity of blood to about **75 times**.
- **Myoglobin** is also called **muscle haemoglobin**.

Features	Haemoglobin	Myoglobin
Location	Blood RBCs	Muscles/Sarcoplasm
Oxygen Transfer	It transfers oxygen from lungs to tissues through blood.	It transfers oxygen from haemoglobin to aerobically respiring muscle cells.
Oxygen Storage	It cannot store oxygen.	It can store oxygen.
Structure	It consists of four polypeptide chains each associated with an iron containing haem group.	It consists of one polypeptide chain associated with an iron containing haem structure.
Capacity for Oxygen	More	Less
Affinity with Oxygen	Less	More
O_2 molecules Bound	4	1

LUNG CAPACITIES

- In an adult human being, when the lungs are fully inflated the total inside capacity of lungs is about **5 litres**.
- Normally when we are at rest or asleep the exchange is only about half a litre. The volume of air taken inside the lungs and expelled during exercise is about 3.5 litres. In other words, there is a **residual volume** of **1.5 litres** even during exercise which cannot be expelled.
- Normally, at rest we inhale and exhale **15-20 times per minute**. During exercise the breathing rate may rise to 30 times per minute. The increased rate and depth of breathing during exercise allows more oxygen to dissolve n blood and supplied be to the active muscles.
- The extra carbon dioxide which the muscle puts into the blood is removed by deep and fast breathing. There is little change in the composition of inhaled and exhaled air during rest or exercise in most of the constituents of the air as seen in the following table.

Oxygen	21	16
Carbon dioxide	0.04	4
Water vapours	Variable	Saturated
Nitrogen	79	79

RESPIRATORY DISEASES

Disease	Infectious disorder of respiratory system	Breakdown of alveoli	Malignant tumor in lungs and show potentially unlimited growth
Cause	*Mycobacterium tuberculosis* (air-born droplets) Malnutrition Poor living conditions	Smoking	Smoking (90%) Other pollutants
Pathogenesis	Contagious disease Lung damage Cough & fever	• Smoke chemicals → Weaken walls of alveoli • Irritants → Smokers cough → Bursting of weak alveoli → ↓ Absorptive area → ↓ Gaseous exchange → Breathlessness and exhaustion • Inflammation of bronchioles → Obstruction → ↑ airway resistance	Malignant tumor Local expansion by invasion and systemic by metastasis Occlusion of respiratory passage
Treatment	Medicine/Antibiotics	Quitting smoking, Bronchodilator, Antibiotics	Chemotherapy & radiotherapy

Asthma

- Asthma is a serious respiratory disease associated with severe paroxysm of difficult breathing, usually followed by a period of complete relief, with recurrence of attack at more or less frequent intervals.
- It is an **allergic reaction** to pollen, spores, cold, humidity, pollution etc. which manifests itself by spasmodic contraction of small bronchiole tubes.
- Asthma results in the release of inflammatory chemicals such as histamines into the circulatory system that cause severe contraction of the bronchiole.

UPTAKE AND TRANSPORT OF MINERALS AND WATER

- The roots of a plant not only anchor the plant body in the soil, but also absorb minerals and water from the soil.
- There are three types of nutrients needed by the plants, carbon dioxide, water and minerals besides light to carry out photosynthesis.
- To get these materials, roots must provide large surface area for absorption, which is achieved by extensive branching.
- The roots bear a dense cluster of tiny hair like structures which are extensions of epidermal cells of roots.
- These are the root hairs, which are in fact the sites where most of the uptake of water and minerals takes place.
- Plants are able to synthesize all their required compounds, with the help of the minerals and H_2O from soil, CO_2 from air, and light energy.
- Most of the minerals enter the root hairs or epidermal cells of roots along with water in bulk flow, but some are taken in by diffusion, facilitated diffusion, or active transport.

Mineral Absorption by Roots

The minerals available to plants for absorption are dissolved in the soil water.

- Their concentration varies according to the fertility and the acidity of the soil, besides other factors.
- When the soil minerals are not in solution but are, bound by ionic bonds to soil particles, they are not available to plants.

Processes Involved in Absorption by Roots

- The uptake of minerals by root cells is a combination of passive uptake and active uptake, involving the use of energy in the form of ATP.
- The passive uptake involves diffusion. The minerals they also move down their concentration gradient through plasmodesmata (symplast pathway) to cells of cortex, endodermis, pericycle and then to sap in xylem cells.
- From here they are pulled up by transpiration pull to different parts of plant,
- The **diffusion** of ions along with water also takes place by mass flow along the apoplast pathway. Ions moving in the apoplast can only reach the endodermis, where casparian strips prevent further progress.
- To cross the endodermis, ions must pass by diffusion or active transport into endodermis cells, entering their cytoplasm, and possibly their vacuoles. The ions then reach the xylem cells.
- Diffusion of ions can also take the vacuolar pathway where the ions move along their concentration gradient through the cell membranes, cytoplasm, and tonoplast (the membrane of vacuoles), and reach the dead xylem cells.

- Most of ions are taken up by the roots by the process of active transport.
- By this method plants can take a mineral that is in higher concentration inside the root cells than in the soil solution.
- In this process molecules and ions move from their low concentration to their higher concentration (i.e. against the concentration gradient), through cell membrane, by the use of energy in the form of ATP.
- Active transport is selective and is dependent on respiration. Some ions move by passive as well as by active transport.
- Some nutrients are carried from the soil to the epidermal cells of roots through their cell membrane by **facilitated diffusion**.
- In this type of diffusion, carrier molecules within the cell membrane transport nutrients across the membrane.
- These carrier molecules are proteins which are present within cell membrane of epidermal and other root cells.

[illegible] OF ROOT

- There are three types of nutrients needed by plants, carbon dioxide, water and minerals besides light to carry out photosynthesis.
- **Root hairs** are dense cluster of tiny hair like structure which is **extensions of epidermal cells of roots.**
- 67 % of the total surface area of the roots is provided by the root hair.
- These are the sites where most of the uptake of water and minerals take place.
- When the soil minerals are not in the solution form rather bound by ionic bond to soil particles, they are not available to plants.
- The rate of absorption of individual mineral which is independent of rate of absorption of water molecules is determined by:

(i) Concentration both inside and outside of the root cells.
(ii) The ease with which it can passively penetrate cell membrane.
(iii) Extent to which carrier molecules and active absorption is involved.

Processes Involved in Absorption by Roots

- Minerals with higher concentration in root cells can also be taken in (against the concentration gradient).
- It utilizes energy in the form of ATP.
- Such type of diffusion that occurs through carrier proteins is called facilitated diffusion.

Uptake of Water by Roots

- Movement of water molecules from a region of higher water potential to a region of lower water potential through a partially permeable membrane is called **osmosis**.
- Movement of water molecules by osmosis into a cell is called **endosmosis**
- Movement of water molecules by osmosis outside a cell is called **exosmosis**.
- Three **pathways** are commonly involved in transport of water and minerals i.e. apoplast, symplast and vacuolar pathway.

Apoplast Pathway

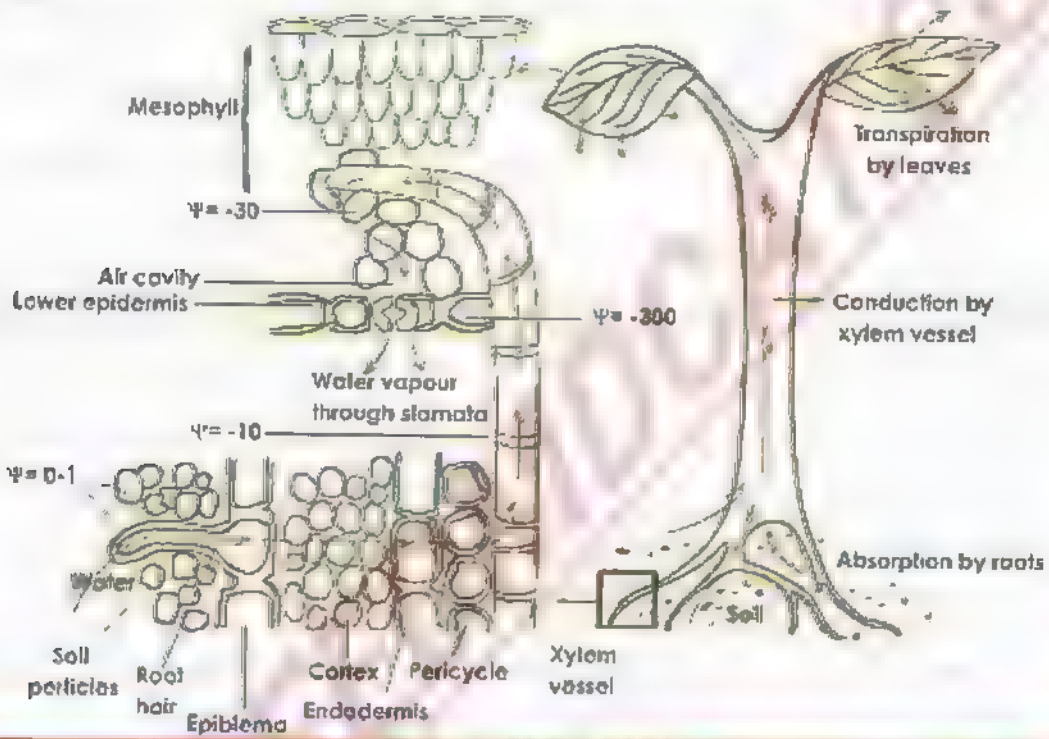
- This involves system of adjacent cell walls which is continuous throughout the plant roots
- In the roots, apoplast pathway becomes discontinuous in the endodermis due to the presence of **casparian strips.**
- Apoplast pathway is of greatest importance for both water and solute transport.

Symplast Pathway

- Symplast pathway is the system of interconnected protoplasts in the root cells.
- Cytoplasms of neighboring cells (protoplast) are connected with one another by **plasmodesmata** (cytoplasmic strands that extend through pores in adjacent cell walls).

Vacuolar Pathway

- In this pathway, water move passively down the concentration gradient from vacuole to vacuole.



Water molecules possess kinetic energy which means that in liquid or gaseous form, they move about rapidly and randomly from one place to another. So, greater the concentration of the water molecules in a system the greater is the total kinetic energy of water molecules. This is called water potential (Ψw).

Factors effecting water potential:

In plant cells two factors determine water potential.

- Solute concentration (Osmotic or solute potential = Ψs)
- Pressure generated when water enters and inflates plant cells (Pressure potential = Ψp).
- **Pure water has maximum water potential which by definition is zero.** Water moves from a region of higher Ψw to lower Ψw,
- All solutions have lower Ψw than pure water and so have negative value of Ψw (at atmospheric pressure and at a defined temperature).

Osmosis:

Osmosis can be defined as:

"The movement of water molecules from a region of higher water potential to a region of lower water potential through a partially permeable membrane".

Osmotic (Solute) Potential = Ψs

The osmotic (solute) potential Ψs is a measure of the change in water potential Ψw) of a system due to the presence of solute molecules. Ψs is always negative. More solute molecules present, lower (more negative) is the Ψs.

Pressure Potential (Ψs)

- If pressure greater than atmospheric pressure is applied to pure water or a solution, its water potential increases. It is equivalent to pumping water from one place to another. Such a situation may arise in living systems.
- When water enters plant cells by osmosis pressure may be built up inside the cell making the cell turgid and increasing the pressure potential. Thus the total water potential is sum of Ψs and Ψp.

Ψw	=	Ψs	+	Ψp
Water potential		**solute potential**		**Pressure potential**

- If we use the term water potential, the tendency for water to move between any two systems can be measured; not just from cell to cell in a plant but also from soil to root from leaf to air or from soil to air. The steeper the potential gradient the faster is the flow of water along it.

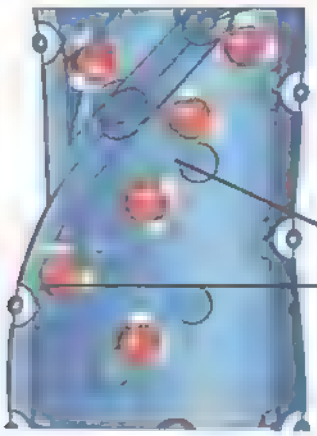
  The following example would help understand the concept of water potential. Two adjacent vacuolated cells are shown with Ψw, Ψp and Ψs.

ASCENT OF SAP

- Pulling upward of water and dissolved minerals towards the leaves through the xylem tissue is called ascent of sap.
- It is explained through **cohesion tension theory**, **root pressure** and **imbibition**.

Cohesion Tension Theory

- It was proposed by Dixon.
- According to this theory, uptake of water **depends upon cohesion and tension**.
- **Cohesion** is the attraction among water molecule (H-bond) forming a solid chain like column within the xylem tubes.
- **Tension** is provided when water chain is pulled up in the xylem. **Transpiration** provides the necessary energy or force. This xylem tension is strong enough to pull water up to **200 meters in plants**.
- **Adhesion** develops between water molecules and cell wall of xylem cells. The composition of cell wall provides necessary adhesion to water molecules that helps water creep up. The **cellulosic component** of cell wall especially has great affinity for water.
- It is essential that the xylem walls should have high **tensile strength**. The lignin and cellulose provides strength to cell wall of xylem vessels.
- Large quantities of water are carried at relatively high speed, **up to 8m/h** being recorded in tall trees, and commonly in **other plants at 1m/h**.
- The total water pulled up in the leaves is transpired, except about **1%**which is used by plants in **various activities including photosynthesis**.



Cohesion and adhesion create tension within xylem that helps move water upward.

Root Pressure

- A pressure created by active secretion of salts and other solutes from root cells into xylem sap, which lowers the water potential of the xylem sap is called root pressure.
- A pressure of 100 – 200 KPa (exceptionally 800 KPa) is generated by root pressure.
- **Guttation or exudation** is a loss of liquid water through **water secreting glands or hydathodes**.
- It is caused by root pressure in small plants like grasses. It is more notable when transpiration is suppressed, and the relative humidity is high at night.

Imbibition

- It was first proposed by Sacks.
- The cell walls components especially **cellulose, pectin and lignin** can take up water and as a result increase in volume, but the components do not dissolve in water, this is called imbibition.
- The root cell walls imbibe water from the soil, and this water moves by apoplast pathway.
- It is a **reversible process**.

Bleeding

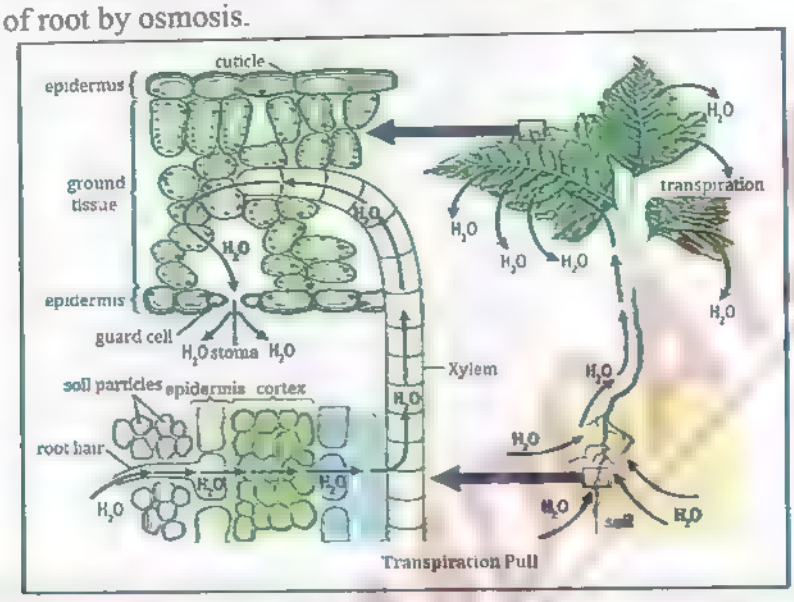
- **Flow of sap from cut ends or surfaces** is called bleeding.
- It is mostly seen in land plants in spring.
- Although the flow of sap is ordinarily slow, a considerable quantity of the sap within a period of 24 hours comes out of the plant, e.g. in some palms when tapped, there may be a flow of sap to the extent of **10-15 L/day**.
- It is created by two factors i.e. **hydrostatic pressure and root pressure**.

TRANSPIRATION AND FACTORS AFFECTING IT

- The **evaporation of water** from aerial parts of plant especially through stomata of leaves is called transpiration.
- As a leaf transpires the water potential of its mesophyll cells drop. This drop causes water to move by osmosis from the xylem cells into dehydrating mesophyll cells.
- The water molecules leaving the xylem are attracted to other water molecules in the same xylem tube by hydrogen bonds. Therefore, when a water molecule moves up the xylem, the process continues all the way till the root, where water is pulled from the xylem cells.
- This pull causes water to move down its concentration gradient transversely from the root epidermis to the cortex by endosmosis and to Pericycle. This pulling force is called

transpiration pull and is so strong that it also reduces the water potential of root epidermal cells.

- Thus water in the soil moves from its higher potential to lower water potential of epidermis of root by osmosis.



Types of transpiration

Feature	Cuticular	Lenticular	Stomatal
Component	Cuticle	Lenticel	Stomata
Structure	Present on upper & lower epidermis, impermeable to water, water lost from thin areas.	Aerating pores formed from bark from cork, in stem of some plants, externally scars or protrusions	Guard cell, dumbbell shaped.
%age	5-7%	1-2%	90%

Factors Effecting Rate of Transpiration

Light

The opening and closing of stomata is directly controlled by the light

Temperature

- Rate of transpiration doubles at every rise of 10°C in temperature.
- Stomata close at very high temperature i.e., 40 -45°C.

CO_2 Concentration

Low concentration of carbon dioxide stimulates the stomata to open.

Humidity and Vapor Pressure

Transpiration increases with increase in dryness of the atmosphere.

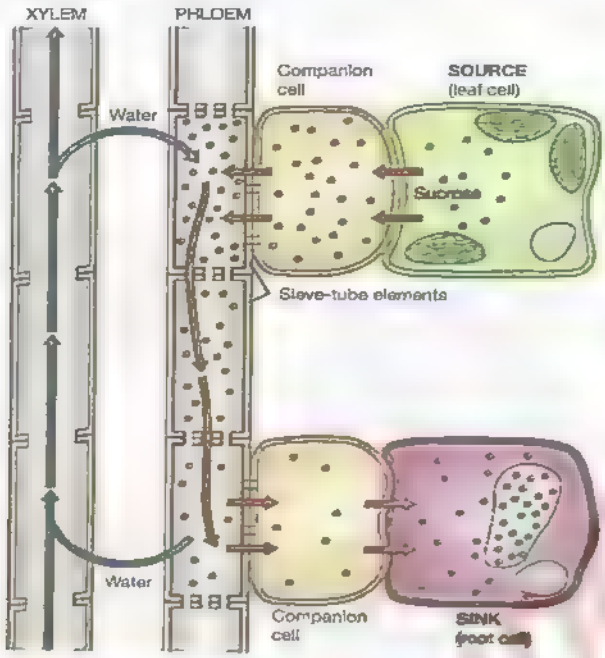
Wind

Air in motion increases the rate of transpiration

Availability of Soil Water

If little water is available to be transported little will lose in the form of transpiration.

-
- The pathway taken by sucrose is symplast in most cases, but in some apoplast Sucrose is actively transported to the sieve elements.
- In the storage sinks e.g. sugar beet, root and sugarcane stem, sucrose is removed into apoplast prior to entering symplast of the sink.



TRANSLOCATION OF ORGANIC SOLUTES

- The phloem constitutes the **inner bark**.
- The cells of phloem that conduct or transport sugars and organic material throughout the plant are called sieve elements.
- Transport or translocation occurs from the area of supply (sources) to area of metabolism or storage called sinks.
- In biennials e.g. root of beet is a sink in first growing season but becomes source in the next growing season, when sugars are utilized in growth of new shoots.
- The movement in phloem is from source to sink in most of the plant during active photosynthesis.

Pressure Flow Theory

- The theory called **pressure flow theory** is the most acceptable theory for the transport in the phloem of angiosperms.
- A hypothesis was first proposed by **Ernst Munch** in 1930. It states that the flow of solution in the sieve elements is driven by an osmotically generated pressure gradient between source and sink.

BLOOD CIRCULATORY SYSTEM

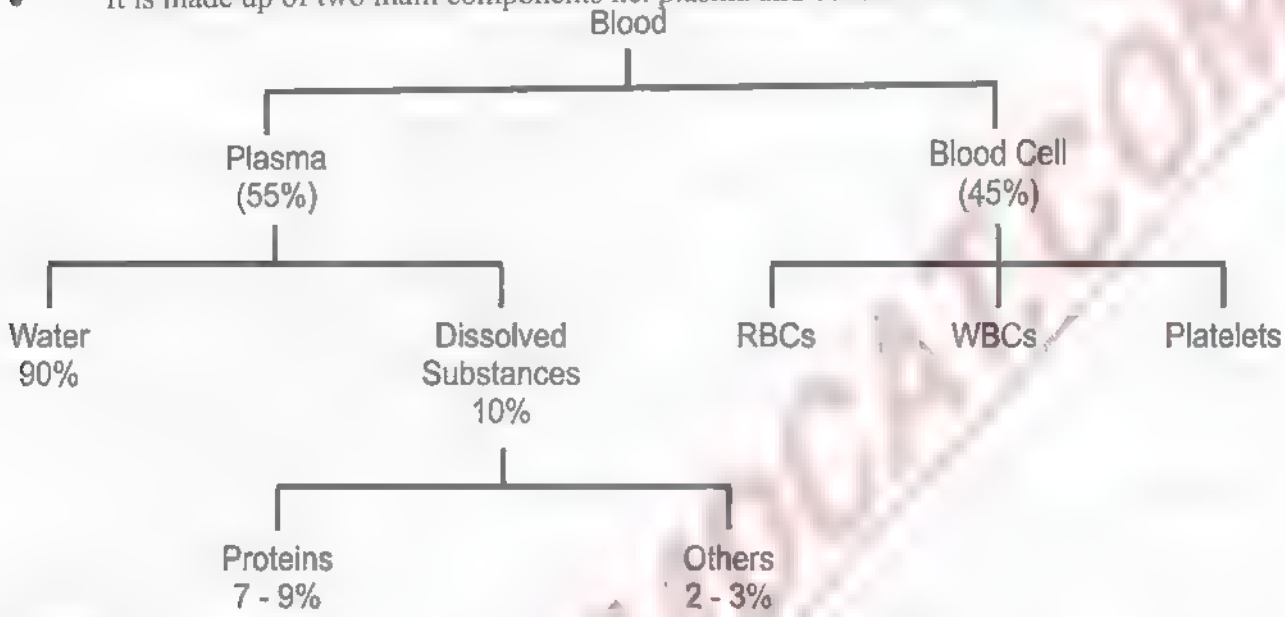
The circulatory system of humans has the same 3 basic components.

(i) Circulating fluid: The blood
(ii) The pumping organ: The heart
(iii) The blood vessels: Arteries, capillaries and veins

Blood

- Blood is the form of **fluid connective tissue** in which dissolved nutrients, respiratory gases, hormones, and wastes are transported through the body.

- The weight of blood in our body is about $1/12^{th}$ of our body.
- The normal pH of blood is 7.4.
- It is made up of two main components i.e. plasma and cells or cell like bodies.



Plasma

Inorganic or Mineral Ions

Inorganic ions and salts make up 0.9% of the plasma by weight. More than 2/3 of this amount is sodium chloride.

Plasma Proteins

- Most of the plasma proteins are **synthesized in liver**. Some of the globulins (immunoglobulins) are produced by lymphocytes and released in plasma or lymph in response to antigen.
- **Thrombin** acts as a catalyst in blood clotting process.
- **Fibrinogen** takes part in blood clotting process.
- **Immunoglobulins** play important role in body's defense against disease.

Organic Nutrients

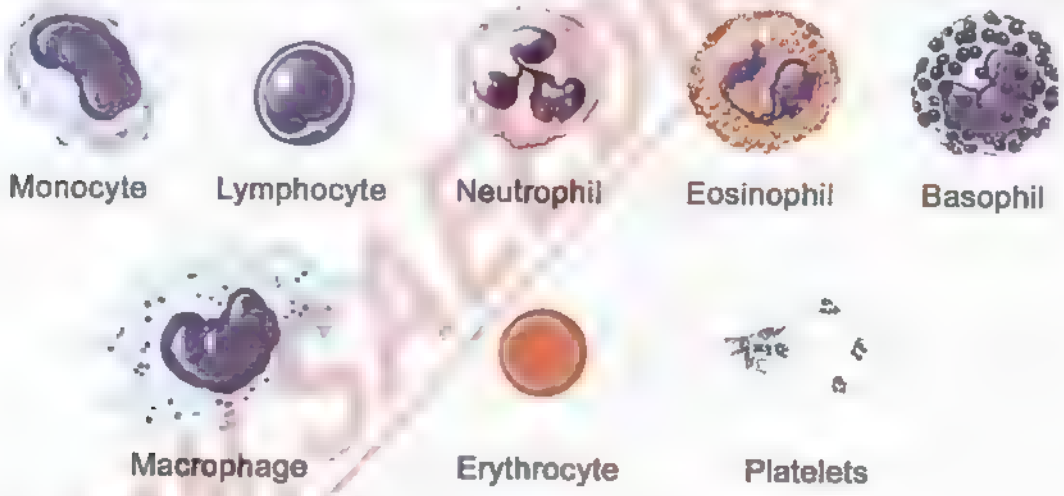
- Organic nutrients include glucose, fats, phospholipids, amino acids and lactic acid.
- Some of them enter blood from intestine (During absorption).
- **Lactic acid** is produced in muscles as a result of glycolysis and is transported by blood to liver.
- **Cholesterol** is either metabolized or used as precursor of steroid hormones

Others

- Nitrogenous wastes are produced as a result of cellular metabolism. These products are carried from the liver where they are produced, to the organs from where they are removed i e. kidneys. Urea and small amounts of uric acid are present in plasma.
- Hormones and gases are also found in plasma.

Types of Blood Cells

Feature	RBCs	WBCs	Platelets
Name	Erythrocytes	Leucocytes	Thrombocytes
Colour	Red	Colorless	Colorless
Formation	• Liver & spleen (embryonic life) • Red bone marrow of sternum, ribs, vertebrae (adult life)	Red bone marrow &lymphatic tissue	Red bone marrow
Size	8μm	Larger than RBC	Smaller than RBC
Shape	Biconcave	Polymorphic	Plate like
Number per mm^3 of blood	5-5.5 million/mm^3 (male) 4-4.5 million/mm^3 (female)	7000-8000/mm^3	250,000/mm^3
Structure	Elastic cell membrane, no nucleus, 95% Hb, 5% enzymes, salts, proteins	Nucleus	No nucleus, membrane bounded Cytoplasmic fragments of cells
Life span	4 months (120 days)	Variable	
Function	Transport of gases	Immunity	Blood clotting



Red Blood Cells

- These are most numerous of the cells in the blood.
- These cells when formed have nucleus, but it is lost before they enter the circulatory fluid or blood.
- The red blood cells once mature do not divide.

White Blood Cells

- There are five different types of WBCs which can be distinguished on the basis of the shape of the nucleus and density of granules in the cytoplasm.
- They can be grouped into two main types, **granulocytes** and **agranulocytes**.

POINT TO PONDER

- **Monocytes** stay in blood for 10-20 hours then enter tissues and become tissue macrophages.
- **Lymphocytes** have life spans of months or even years; but this depends on the body's need for these cells.
- **Monocytes** and **neutrophils** travel through capillaries and feed on bacterial invaders or other foreign cells, including cancer cells.
- **Macrophages** and **neutrophils** typically die in a process and their dead bodies accumulate and contribute to the white substance called pus, seen at infection sites.

Main Categories of WBC

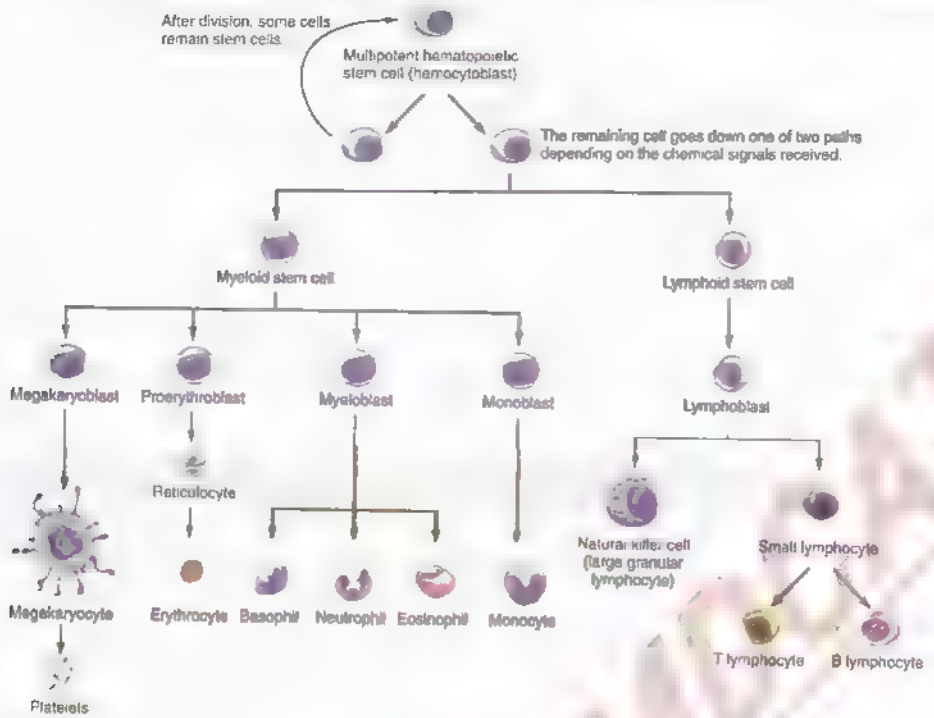
Feature	Granulocytes	Agranulocytes
Formation	Red Bone Marrow	Bone Marrow &Lymphoid tissue (Lymph nodes, spleen, tonsils, adenoids, thymus)
Nucleus	Incompletely divided/ Spherical	Spherical to lobed
Cytoplasm	Granular	Agranular
Examples	Neutrophils, Eosinophils, Basophils	Monocytes, Lymphocytes (B and T)

Sub-Categories of WBCs

Feature	Neutrophils	Eosinophils	Basophils	Monocytes	Lymphocytes
Size in relation of RBC	Twice	Twice	Twice	Twice to thrice	Slightly larger
Nucleus	2-5 lobed	Bilobed	Bilobed	Round to lobed	Round, nearly filling cell
%age	62%	2%	<1%	3%	32%
Function	Destruction of small particles by phagocytosis	Inactivate inflammation producing substances & attack parasites	Release heparin to prevent blood clots & histamine to cause inflammation	Destroy large particles by phagocyto-sis	Immune response by producing antibodies

Platelets

- These are not cells but are fragments of large cells called **megakaryocytes**.
- Platelets help in conversion of fibrinogen, a soluble plasma protein, into insoluble form, fibrin. The fibrin threads enmesh RBCs and other platelets in the area of damaged tissue, ultimately forming a **blood clot**.
- The **clot** serves as temporary seal to prevent bleeding until the damaged tissue can be repaired.



Functions of Blood

(i) Maintenance of Osmotic Balance

- Plasma proteins maintain colloid osmotic pressure of blood.
- 75% role is played by albumins, 25% by globulins and almost none by fibrinogen

(ii) Transportation

- Blood helps to transport nutrients, water, salts and waste products.
- Hormones are transported by blood from the endocrine tissues to the target cells.
- Gases (O_2 and CO_2) are transported by blood.

(iii) Homeostasis

- Blood acts as a buffer to maintain the acid base balance i.e. concentration of H^+ and OH^- ions in the body.
- Blood helps in maintaining the body temperature, concentration of water and salts, thus helps in homeostasis.
- Blood helps the body in maintaining the internal environment, by producing heparin, histamine and also by maintaining the amounts of chemicals.

(iv) Defense/ Immunity

- Blood helps in body defenses against disease. Neutrophils and monocytes engulf and destroy invading microorganisms e.g. bacteria.
- Blood provides immunity by the lymphocytes.
- Blood produces interferons and antitoxins which are proteins and protect our body from nucleic acids and toxins of invading organisms.

POINT TO PONDER

(v) Blood Clotting

- It helps in blood clotting process and seals the wounds that stop entry of pathogens into the body.

(vi) Exchange of Materials

- Walls of capillaries help in exchange of materials between blood and body tissue through blood capillaries via interstitial fluid.

Introduction

- The human heart is **located in the chest cavity** between lungs slightly left **of the** sternum.
- The heart contracts automatically with rhythmicity, under the **control of the autonomic nervous system**.

Pericardium

- The heart is enclosed in a double membranous sac – the pericardial cavity, which contains the pericardial fluid.
- **Pericardium** protects the heart, prevents it from over extension.
- **Pericardial fluid** reduces friction during contraction.

Heart Walls

- The wall of the heart is composed of three layers: Epicardium, Myocardium and Endocardium.
- **Epicardium** is a thin serous membrane.
- **Myocardium** of heart is made up of special type of muscles, the cardiac muscles. Their arrangement and mechanism of contraction is essentially same as skeletal muscles except that they are branched cells. Successive cells are separated by junctions called **intercalated discs**.
- Endocardium consists of simple squamous epithelium over a layer of connective tissue.

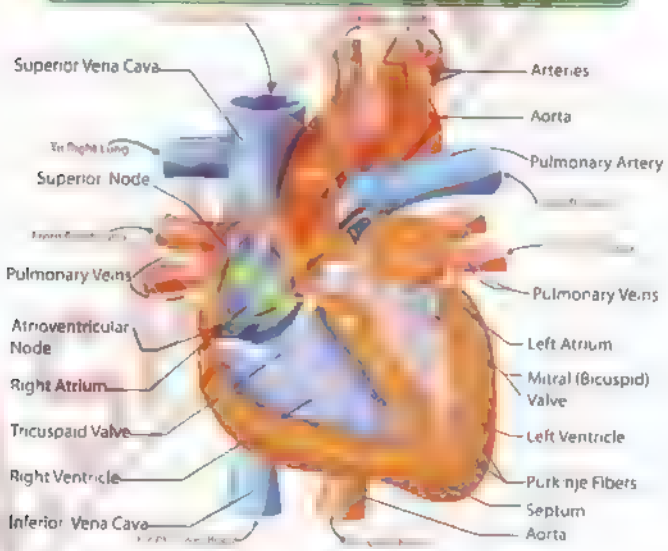
Heart Chambers

- There are **four chambers of heart**: two upper thin walled atria and two lower thick walled ventricles.
- Right atrium receives deoxygenated blood from superior and inferior vena cava and the coronary sinus. The left atrium receives the oxygenated blood from four pulmonary veins.
- Atria pump blood to ventricles. Atria open into the ventricles through atrioventricular apertures.
- Right ventricle pumps deoxygenated blood to lungs through pulmonary arteries while left ventricle pumps blood to all organs except lungs through aorta.
- Right side of the heart is concerned with deoxygenated blood and left side with oxygenated blood.
- Complete separation of deoxygenated and oxygenated blood is maintained by formation of **septa** (interatrial and interventricular).

- Atria are separated from each other by interatrial septum and ventricles by interventricular septum.
- The wall of left ventricle is thicker (3 times) than that of right ventricle.

Heart Valves

- **Tricuspid or the Right AV valve** (3 flaps) is present between right atrium and right ventricle.
- **Bicuspid valve/ Left AV valve/ Mitral valve** (2 flaps) is present between left atrium and left ventricle.
- These flaps are attached with fibrous cords called **chordae tendinae**, to the **papillary muscles** which are extensions of the wall of the ventricles. Papillary muscles contract when the ventricles contract and prevent the valves from opening into the atria by pulling on the chordaetendinae attached to the valve cusps.
- **Semilunar valves** are present at base of aorta and pulmonary trunk. Each valve consists of three pockets like semilunar cusps.



Blood Circulation Through Heart

- Heart functions as a double pump and is responsible for pulmonary and systemic circulation.

Pulmonary Circulation

Deoxygenated Blood

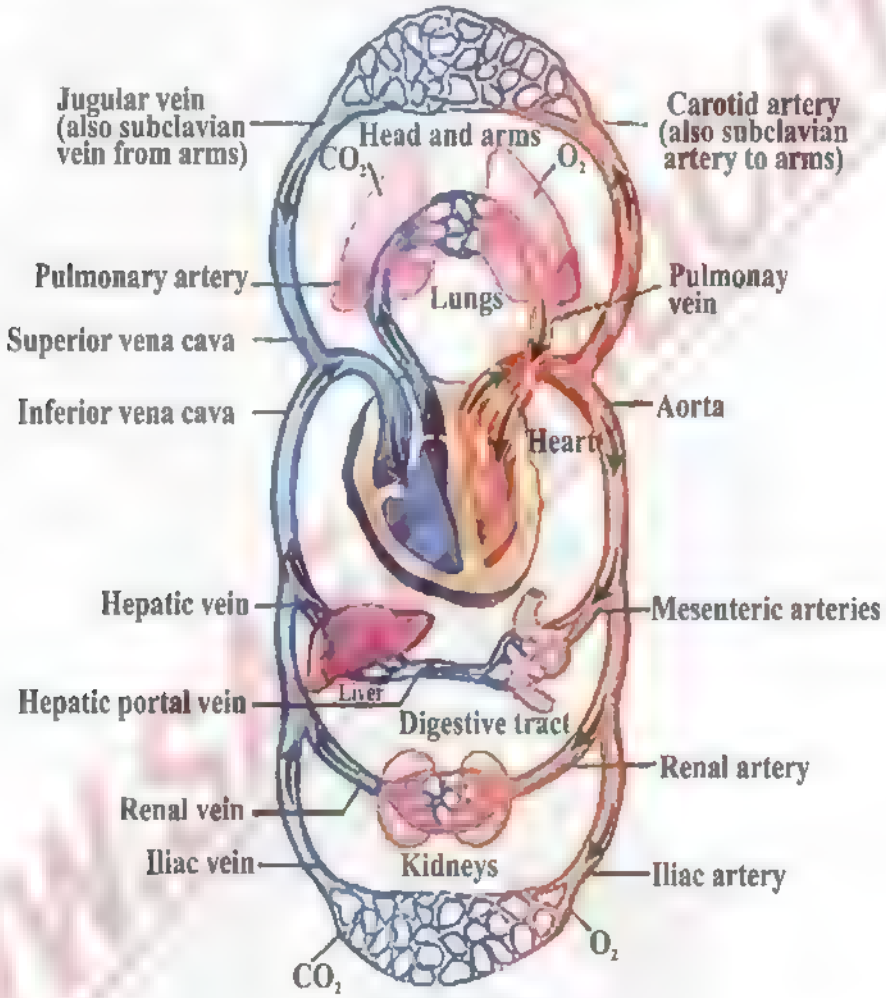
Vena cavae (Deoxygenated Blood) → Right Atrium → Right Ventricle → Pulmonary Trunk → Right and Left Pulmonary Arteries → Lungs

Oxygenated Blood

Lungs → Pulmonary Veins (Oxygenated Blood) → Left Atrium → Left Ventricle → Systemic /Aortic Circulation

Systemic Circulation

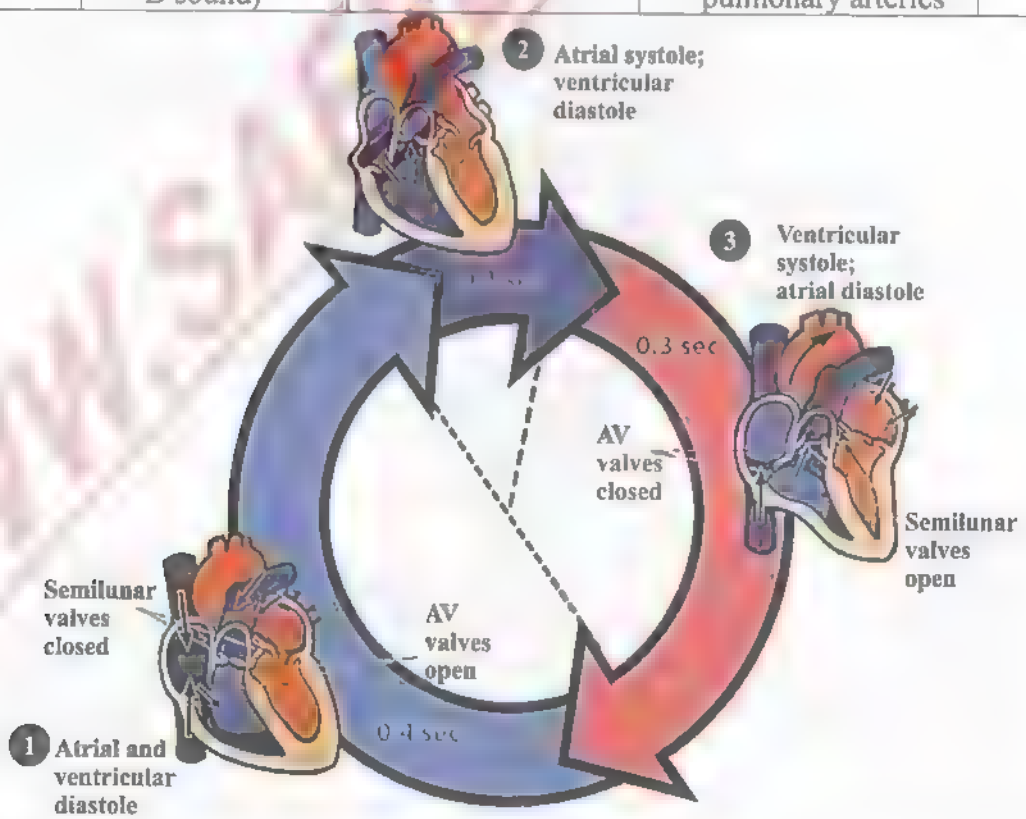
- At the **base of aorta**, first pair of arteries, the coronary arteries arise and supply blood to heart.
- Three branches arise from **arch of aorta** that supply blood to head, shoulders and arms.
- The aorta descends down in the chest cavity. It gives many branches to the chest wall.
- In abdominal region, it supplies to different parts of alimentary canal, kidneys and lower abdomen.
- At the end of abdomen, aorta bifurcates into iliac arteries which supply blood to legs.
- **Superior vena cava** collects blood from head, shoulder and arms, while **inferior vena cava** from all other parts.



The Cardiac Cycle

- It is the sequence of events which take place during the completion of one heartbeat.
- Heart beat involves three distinct stages i.e. atrial systole, ventricular systole and diastole.
- Relaxed period of heart chambers is called **diastole** and contraction is called **systole**.
- One complete **heartbeat** consists of one systole and one diastole and lasts for about **0.8 seconds**.
- In one's life, heart contracts about 2.5 billion times, without stopping.

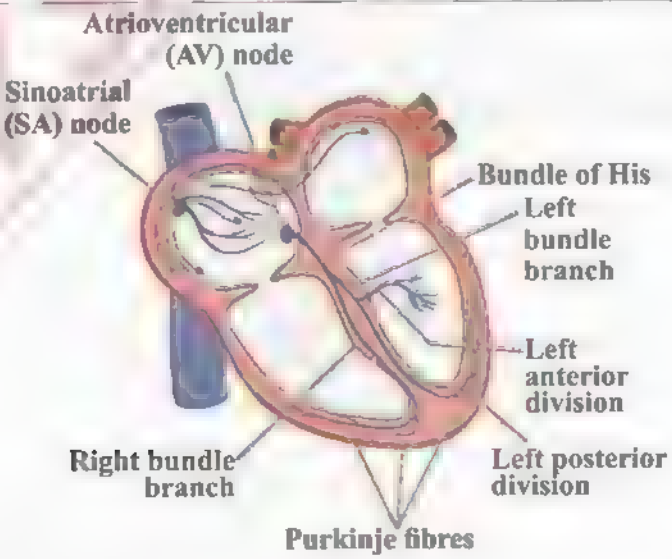
Diastole (Relaxation)	• AV valves open • SL valves closed	• Atria relaxed • Deoxygenated blood enters right atrium by vena cava • Oxygenated blood enters left atrium by pulmonary veins	• Ventricles relaxed • Deoxygenated blood enters right ventricle through right atrium • Oxygenated blood enters left ventricle through left atrium.	0.4 sec
Atrial Systole	• AV valves open • SL valves closed	Muscles of atria contract and pump blood to ventricles	Ventricles are relaxed and receive blood from atria.	0.1 sec
Ventricular systole	• AV valves close (LUBB sound) • SL valves open at the beginning • SL valves close at the end of systole(DUB B sound)	Atria are relaxed during this phase	• Both ventricles contract • Left ventricle pumps oxygenated blood via aorta to all parts of body • Right ventricle pumps deoxygenated blood to lungs via pulmonary arteries	0.3 secapprox.



Mechanism of Heart Excitation and Contraction

- Heartbeat starts when the sino-atrial node (**pacemaker** at the upper end of right atrium) sends out electrical impulses to the atrial muscles, thus causing both atria to contract.
- The **sino-atrial node** consists of small number of diffusely oriented cardiac fibres, possessing few myofibrils and few nerve endings from the autonomic nervous system. It has been developed from sinus venosus.
- Impulses from the SA node travel to the musculature of the atrium and to atrio-ventricular node (AV).
- There is a delay of approximately 0.15 seconds in conductance from the S-A node to A-V node, permitting atrial systole to be completed before ventricular systole begins.
- From AV node, AV bundle of muscle fibers propagate the regulatory impulses via excitable fibers in the interventricular septum to the myocardium of the ventricles.
- Pacemaker is responsible for initiating the impulses, which trigger the heartbeat rate.
- ANS → SA Node → Atrial Musculature + AV Node (Inter-nodal fibers)
- AV Node → Bundle of His → Right and Left Bundle Branches → Purkinje Fibers → Ventricular Musculature

Location	Upper end of right atrium	Junction of right atrium and right ventricle
Structure	• Diffusely oriented cardiac fibers • Few myofibrils • Few nerve endings from autonomic nervous system	• Diffusely oriented cardiac fibers • Few myofibrils • Few nerve endings from autonomic nervous system
Function	• Initiates heartbeat by generating electrical impulses • It sends impulses to the atrial muscles and causes them to contract.	It acts as relay and transfers the impulses to wall of ventricles
Direction of impulse	S.A node → Wall of atria → delay of 0.15 sec → AV node	AV node → Bundle of His → Bundle branches → Purkinje fibers → Wall of Ventricles



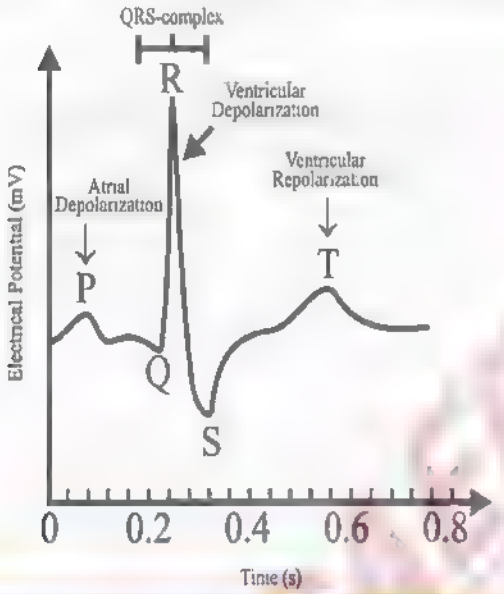
Electrocardiogram

- As the cardiac impulses pass through heart, these also spread into surrounding tissues. Electrodes are placed on opposite sides of the heart and electrical potentials generated by these currents can be recorded.
- This recording is called **electrocardiogram** which is taken by ECG machine.
- It helps to diagnose the abnormalities in the rhythmicity and conduction system of the heart.
- In an ECG:

(i) **P wave** represents atrial contraction.

(ii) **QRS complex** represents ventricular contraction.

(iii) **T wave** represents ventricular relaxation.



BLOOD VESSELS

- Blood vessels are involved in the transportation of circulatory fluid(blood). They are three types of blood vessels i.e. Arteries, Veins and Capillaries

Feature	Arteries	Veins	Capillaries
Direction of Blood Flow	They transport blood away from heart to various parts of body	They collect blood from various parts of body and transport it towards heart	They link arteries with veins
Type of Blood	All carry oxygenated blood except pulmonary arteries	All carry deoxygenated blood except pulmonary veins	They have mixed blood
Structure	• Three layers • Outer: Connective	• Three layers • Outer: Connective	Only one cell thick endothelium

	tissue + Elastic fibers • Middle: Circular smooth muscles + Elastic fibers • Inner: Endothelium	Tissue • Middle: Circular smooth muscles + Thin elastic membrane • Inner: Endothelium	
Elasticity	Elastic	Less elastic	Inelastic
Pulsatile Nature	Pulsatile	Non-pulsatile	Non-pulsatile
Valves	No valves except at the base of aorta& pulmonary trunk	Semilunar Valves are present to prevent the backflow of blood	No valves
Blood Pressure	High blood pressure	Low blood pressure	Falling pressure in these
Rate of Blood Flow	Rapid blood flow 400-500 mm/sec	Increases from smaller to larger veins	Blood flow is slowest 1mm/sec
Exchange of Material	No exchange of materials	No exchange of materials	Exchange of materials
Bore and Thickness	Have smaller bore and thick walls	Have larger bore and thin walls	Larger bore; wall one cell in thickness

Some Other Features

Arteries

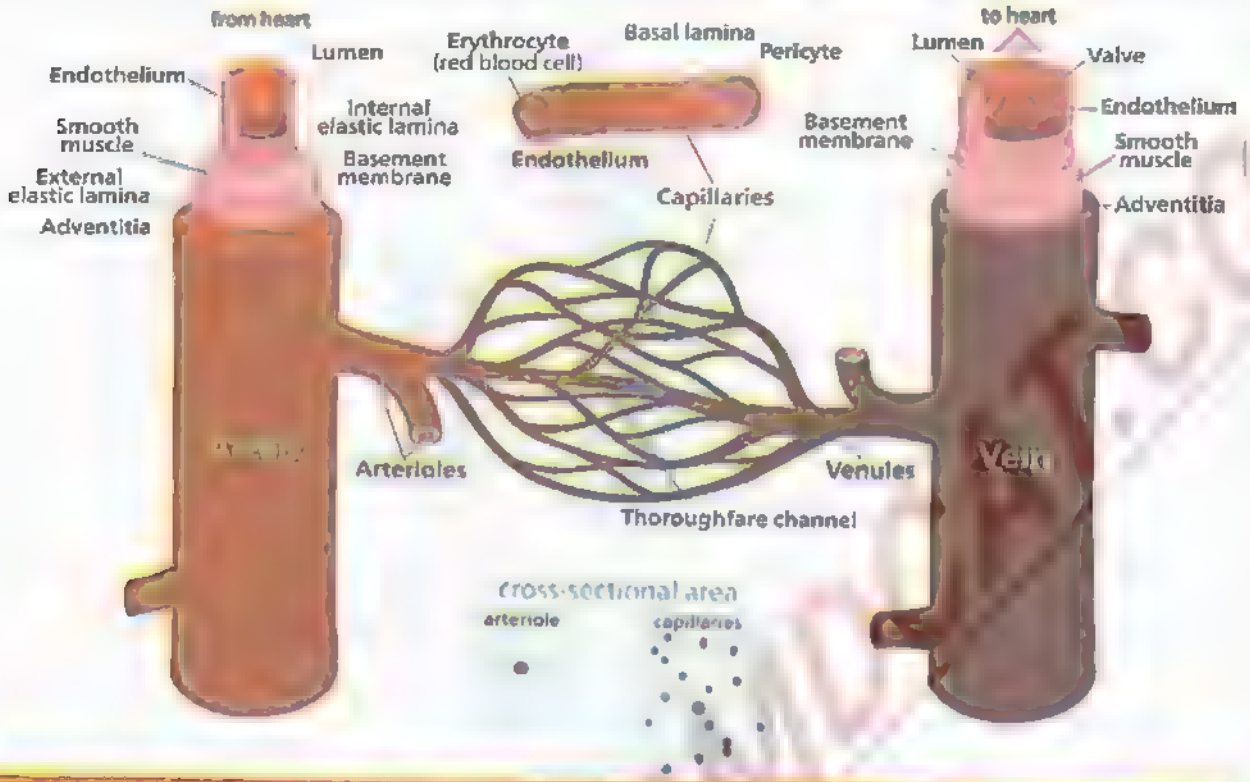
- Contraction of circular smooth muscles of arteries and arterioles is under control of the nervous system and endocrine system.
- When stimulated the muscles contract, constricting the arterioles (vasoconstriction) and thus reducing the flow of blood in them and vice versa.

Veins

- In veins, muscle contraction also assists (squash blood vessels) in blood flow return towards heart along with valves.
- Portal veins carry blood to any organ other than the heart. For example, hepatic portal vein carries blood from intestine to liver.

Capillaries

- In liver, every cell is in direct contact with capillary.
- The diameter of a capillary can be altered by nervous stimulation, which tends to close them and by chemicals, such as histamine, which dilate them.
- The change in diameter is brought about by change in shape of cells.
- The pre-capillary sphincters also regulate the amount of blood flowing in capillaries.
- Exchange of materials between blood and cells occurs through with extracellular fluid. It involves diffusion, active transport and endocytosis.

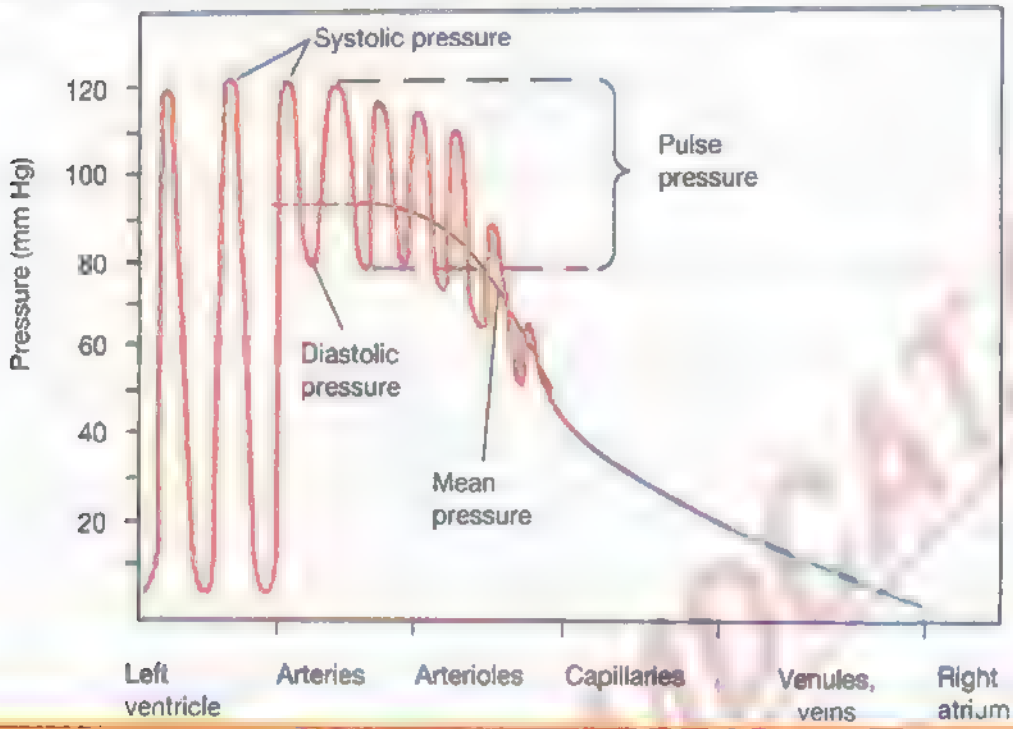


Blood Pressure

- "It is the measure of force with which blood pushes up per unit area against the walls of blood vessels".
- It is measured in mmHg.
- It is the force that keeps blood flowing from the heart to all the capillary networks in the body.
- The blood pressure is generated by the contraction of ventricles. This is called **systolic pressure**.
- When the ventricles relax, the atrial pressure is lowest and is called **diastolic pressure**.
- Blood pressure consistently decreases in the following pathway:
  Aorta → Arteries → Capillaries →Veins → Vena cava
- The normal systolic blood pressure is **120 mm Hg** which is during ventricular systole.
- The normal diastolic blood pressure is **75-85 mm Hg** which is during diastole of the heart.

Rate of Blood Flow

- The rate of blood flow tends to fall as the blood moves through the branching arteries and arterioles, the rate is lowest in the capillaries; and increases again in the venules and veins.
- These charges in rate of blood flow result from changes in the total cross sectional area of the vessel system. The flow of blood in veins is maintained by the contraction of surrounding muscles and the action of semilunar valves which prevent back flow of blood.
- Muscular activity including breathing movements helps normal flow of blood in the blood vessel.



LYMPHATIC SYSTEM

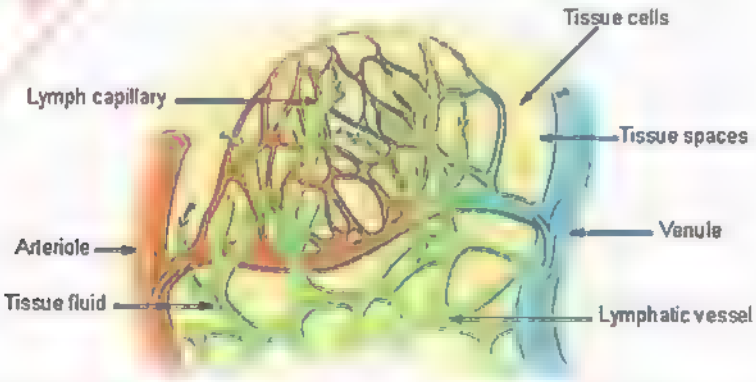
Introduction

- This system is responsible for the **transport and returning of material** from the tissues of the body to the blood.
- It **comprises of** lymph capillaries, lymph vessels, lymphoid masses, lymph nodes, and lymph.

Components of Lymphatic System

Lymph

- **Lymph** is the fluid which flows in the system.
- The **lymph vessels** empty in veins; so lymph is a fluid in transit between interstitial fluid and the blood.
- The **intercellular spaces** in the walls of lymph vessels are larger than those of the capillaries of blood vascular system.
- In an average person, about three liters more fluid leaves the blood capillaries that are re-absorbed by them each day.
- After a fatty meal, the fat globules may make up 1% of the lymph.



Lymph Vessels

- **Lacteals** are the branches of lymph capillaries inside villi of intestine.
- **Lymph capillaries** are blind ended structures.
- Largest lymph vessel is thoracic duct.
- Lymph vessels which carry lymph towards lymph nodes are called **afferent lymph vessels**.
- Lymph vessels which carry lymph away from lymph nodes are called **efferent lymph vessels**.

Lymph Nodes

- These are masses of connective tissue where lymphocytes are present are called **lymph nodes**.
- Lymph nodes are present in neck region, axilla and groin of humans.
- Several afferent lymph vessels enter a lymph node, which is drained by single efferent lymph vessel.
- Lymph nodes act as filter for lymph as do spleen for blood.

Flow of Lymph

- Direction of flow of lymph is:
  Lymph Capillaries → Smaller Lymph Vessels → Larger Lymph Vessels → Thoracic Duct → Subclavian Vein
- The flow of lymph is maintained by:

(i) Activity of skeletal muscles
(ii) Movement of viscera
(iii) Breathing movements
(iv) Semilunar valves that prevent backward flow

Functions of Lymphatic System

- Return of excess extracellular fluid and proteins to the blood.
- Absorption of large fat globules by lacteals of villi.
- Play important role in the defense system of the body. Lymphocytes and macrophages present inside lymph nodes kill bacteria and viruses.

Immunity

- The capacity to recognize the intrusion of any material foreign to the body and to mobilize cells and cell products to help remove the particular sort of foreign material with greater speed and effectiveness is called **immunity**.
- There are three defense lines of our body:

(i) First defense line is provided by physical and chemical barriers.
(ii) Second defense line by phagocytes.
(iii) Third defense line by the immune system.

- First and second defense lines are non-specific while 3rd defense line is specific.
- Skin, mucous membrane and blood clot are physical barriers.
- HCl and lysozyme are examples of chemical barriers.
- Phagocytes and lymphocytes are example of cellular/ biological barriers.

Components of Immune System

- Immune system forms 3rd defense line of our body.
- It is derived from mesoderm.

- It has two main components i.e. lymphocytes and antibodies.
- **Antigen or immunogen** is a foreign substance, often a protein which stimulates the formation of antibodies.

Lymphocytes

- Lymphocytes are examples of agranulocytes and belong to WBCs.
- There are two major types of lymphocytes i.e. T & B lymphocytes.
- T lymphocytes have been given name due to their relationship with thymus glands. Thymus has role in maturation of T-lymphocytes and makes them immunologically competent. T-cells originate from stem cells in bone marrow. After early embryonic development, the newly forming T-cells migrate to thymus gland for processing. T-lymphocytes are further divided into following categories:

(i) **Helper T-lymphocytes** recognize the antigen and inform other cells by releasing specific chemical substances (cytokines).

(ii) **Suppressor T-lymphocytes** are involved in controlling immune response.

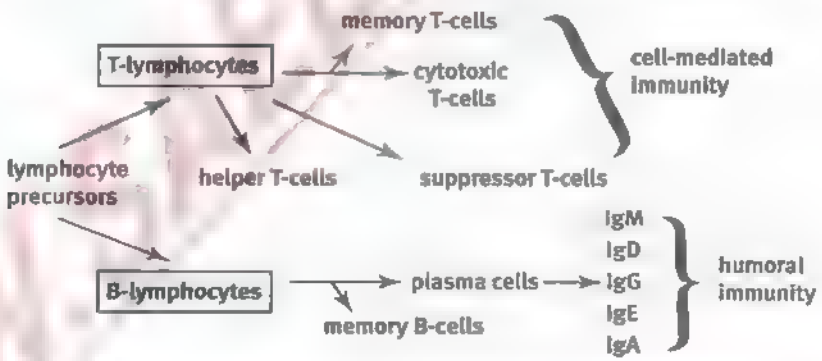
(iii) **Cytotoxic T-lymphocytes** are involved in direct killing or destroying of antigens. For destruction, they usually depend upon lysosomes and peroxisomes.

(iv) **Memory T-lymphocytes** keep information/ memory of the antigen to protect body for next attack by same antigen.

- **B-lymphocytes** have been given name due to their 1st discovery from Bursa of Fabricius, which is a lymphoid tissue in birds around cloaca. In humans, these are produced and released in mature form from bone marrow. After stimulation by antigen, they are activated and start dividing and form:

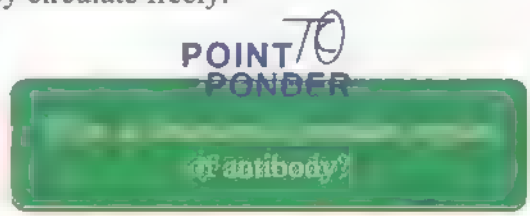
(i) **Plasma cells clone** which synthesize and secrete antibodies in plasma and other body fluids.

(ii) **Memory B-cells** which keep information/ memory of antigen encountered.



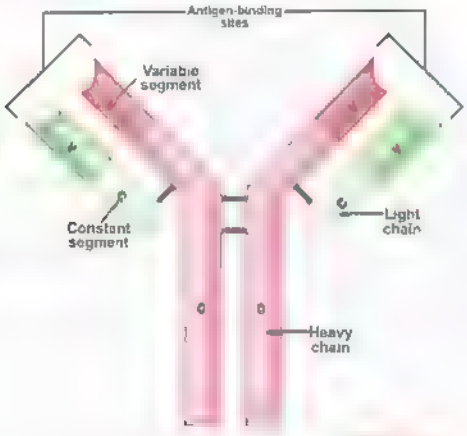
Antibodies

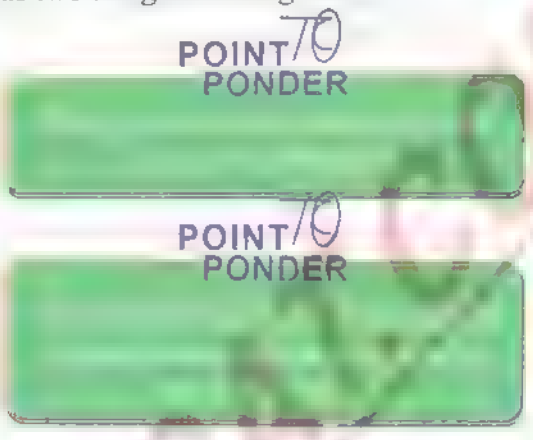
- **Antibodies/ Immunoglobulins** are globular proteins, manufactured by B-lymphocytes, then secreted into the lymph and blood where they circulate freely.
- These are Y shaped molecules and **possess quaternary structure.**
- Each antibody consists of four polypeptide chains; **two heavy chains and two light chains.**
- Each chain has a constant region and variable region.
- In constant region, the amino acid sequence is constant within a particular immunoglobulin class.

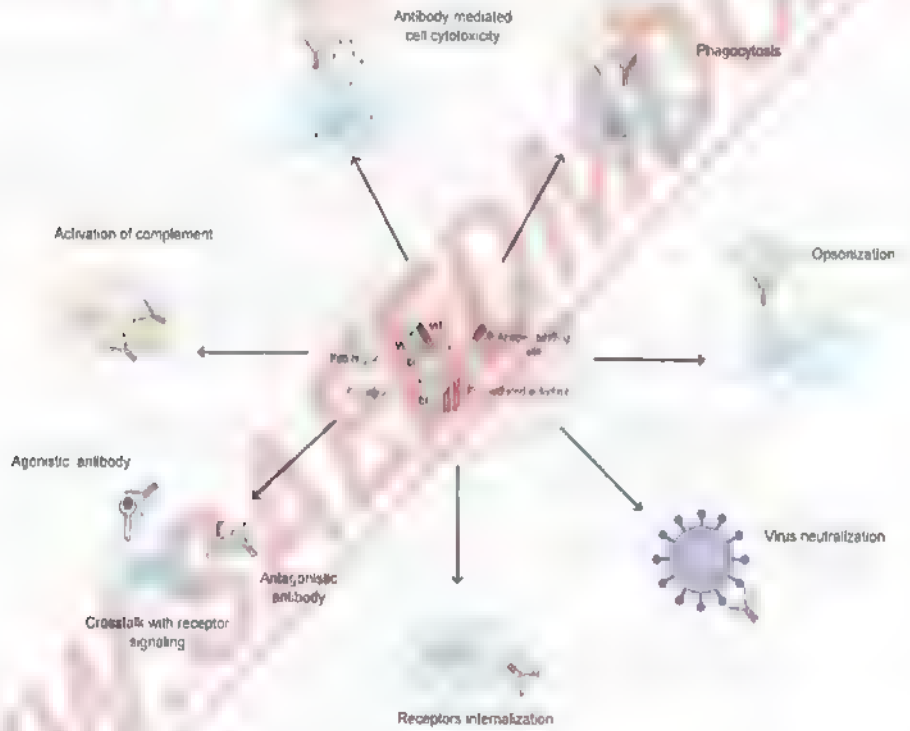


- Variable segment consists of different amino acid sequence in every antibody. Therefore, they act as antigen binding sites. Each antibody has two antigen binding sites.

Modes of Action of Antibodies







Types of Immunity

- There are two basic types of immunity: inborn or innate immunity and acquired or adaptive immunity.

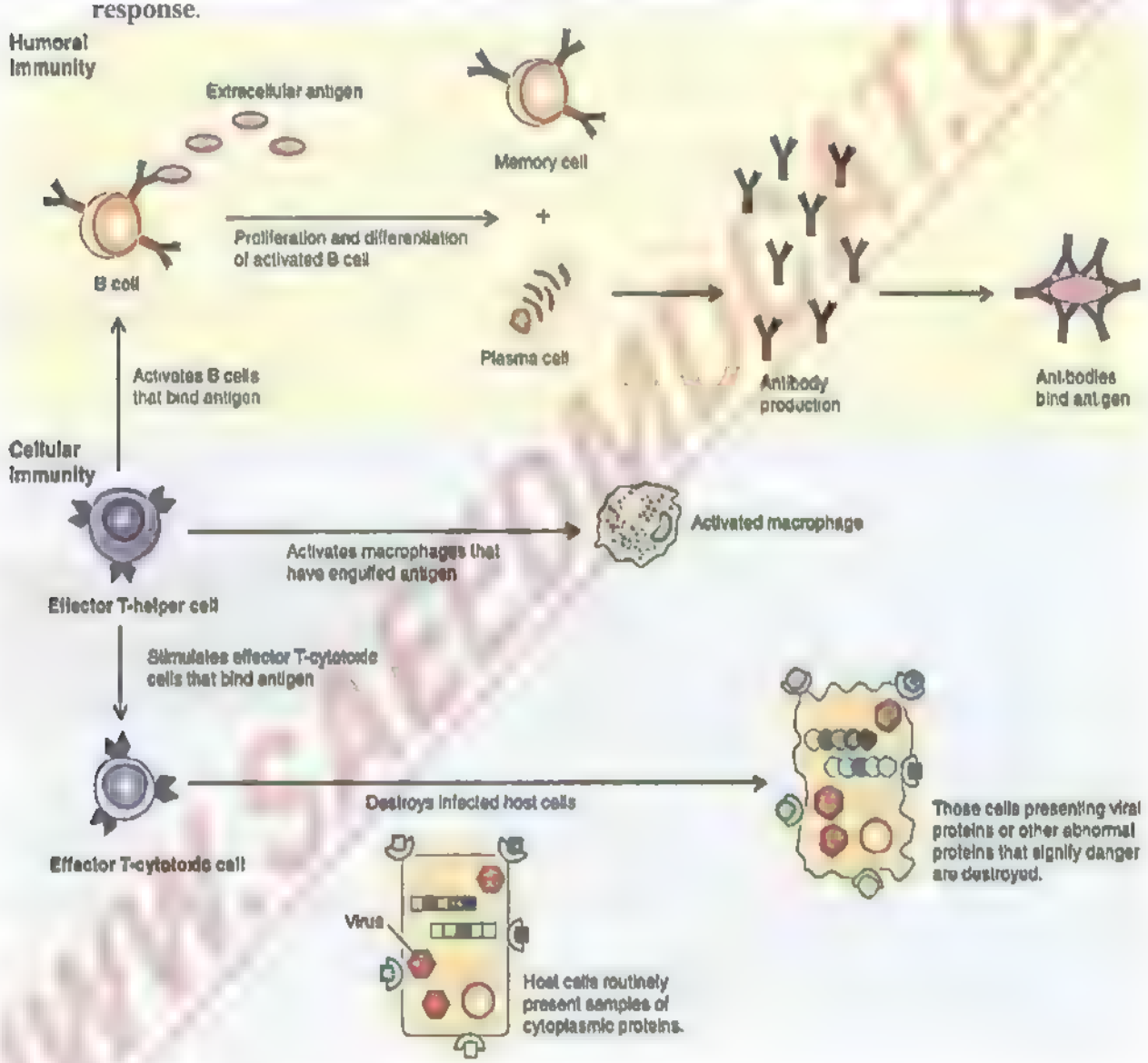
Innate Immunity

- The ability of the innate immunity to kill microorganisms is not specific.
- First and second lines of defense are part of innate immunity.

Acquired Immunity

- Highly specific protection is provided by innate immunity, but it takes several days for this system to become fully functional.
- There are two types of acquired immune responses i.e. cell-mediated response and antibody-mediated or humoral immune response.

- T-cells recognize antigen and then combat microorganisms and also responsible for rejection of foreign transplanted tissue if it is not properly matched. This is called **cell mediated response.**
- B-cells recognize antigen and form plasma cell clone. These plasma cells synthesize and liberate antibodies into the blood plasma and tissue fluid. Here antibodies attach to the surfaces of bacteria and speed up their phagocytosis. Some antibodies behave as antitoxins for neutralization of toxins produces by microorganisms. This is called **humoral immune response.**



Types of Acquired Immunity

- There are two types of acquired immunity:

(i) Active Immunity

(ii) Passive Immunity

- The method of passive immunization is used to combat active infections of tetanus, infectious hepatitis, rabies, snakebite venom etc.
- These are further divided into natural and artificial immunity.

Feature	Active Immunity	Passive Immunity
Production of Immunity	Produced because of entry of antigen	Produced because of entry of antibodies.
Source of Antibodies	Body is stimulated to produce antibodies	Antibodies are introduced from other source.
Substance Entering	Antigen	Antiserum
Response	Delayed immune response	Immediate immune response
Results	Prolonged results	Short acting
Memory cell production	✓	✗
Role	Preventive	Preventive and curative

Natural Active Immunity

- When a person is exposed to an infection (antigen) becomes ill and in most cases survives, then this immunity developed against that disease is called **natural active immunity**.

Artificial Active Immunity (Vaccination)

- The use of vaccines, which stimulates the production of antibodies in the body, and making a person immune against the diseases or infection, is called **artificial active immunity**. The process is called vaccination.
- This active immunity has been achieved by artificially introducing; antigens in the body.

Natural Passive Immunity

- If the source of antibodies is natural, then type of immunity will be called as natural passive immunity.
- For example, antibodies from a mother can cross the placenta and enter her fetus. In this way they provide protection for the baby until its own immune system is fully functional.
- This immunity may also be provided by colostrum, the first secretion of the mammary glands. The baby absorbs the antibodies through its gut.

Artificial Passive Immunity

- Antibodies which have been formed in one individual are extracted and then injected into the blood of another individual.
- In the case of snakebite venom, passive immunity is produced by antitoxins, so the serum is called anti-venom serum.
- Similarly, specific antibodies used for combating tetanus and diphtheria are cultured and injected into humans.

TOPIC-11 HOMEOSTASIS

- Mechanism of Homeostasis
- Homeostatic Feedback Mechanisms
- Osmoregulation
- Osmoregulation in animals of different environment
- Nitrogen Containing Excretory Products
- Excretory System of Humans
- Structure and Function of Kidney
- Nephron
- Renal Disorders
- Classification of Animals Based on Thermoregulation
- Thermoregulation in Humans

MECHANISM OF HOMEOSTASIS

Homeostasis

- The protection of internal environment from the harms of fluctuations in external environment is termed as homeostasis.
- The homeostasis keeps the internal fluctuations in a **narrow range**.
- Most susceptible components of internal environment that may be affected by fluctuations in external environments are water, solutes and temperature.
- The mechanism an organism has adapted to eliminate harmful nitrogenous wastes depends upon the availability of water.
- The mechanism of regulation, generally between organism and its environment, of solute and the gain and loss of water is **osmoregulation.**
- The mechanism which eliminates nitrogenous waste is referred as **excretion,** whereas maintenance of internal temperature within a tolerable range is designated as **thermoregulation.**

Mechanism of Homeostasis

- The coordination makes possible the integration of functions essential to organismic behavior.
- External environment may show changes within broad range.
- Intracellular and extracellular internal environments also keep fluctuating but in narrow range. Here, in addition to solute and water various essential metabolites, hormones etc. are kept in required range. This control is brought about by control system.
- Living control system has three components i.e. **receptor, control center and effectors.**

Stimulus

- Any change in internal or external environment is called stimulus.
- Change in temperature of atmosphere and light are examples of external stimuli.
- Changes in solute or water concentration in blood are examples of internal stimuli.

Receptors

- These are the structures which detect change in external or internal environment.
- The receptors may be cells (e.g. rod and cone cells of eye), neuron endings (e.g. Pacinian corpuscles) and organs (e.g. nose, ear).

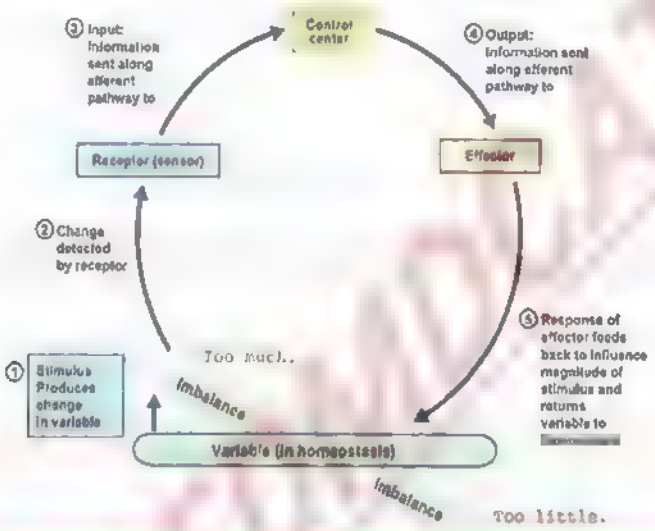
- Receptors are also classified on base of type of stimuli e.g. chemoreceptors, mechanoreceptors, thermoreceptors etc.

Control Centre

- It integrates data from receptor with data stored as set point.
- Control centre of most of the activities of humans is brain.

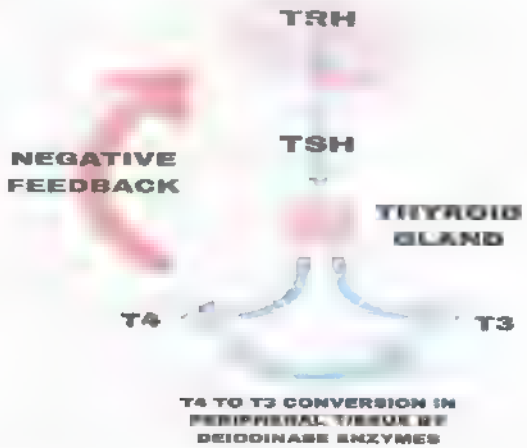
Effectors

- These are the structures which respond to stimulus.
- Effectors are either muscles or glands. Muscles show response by contraction while glands through secretions.



HOMEOSTATIC FEEDBACK MECHANISM

- Feedback mechanism is a type of interaction in which a controlling mechanism is itself controlled by the products of reactions it is controlling.
- For proper body functions, two opposing systems are needed, if there are accelerators, there must be inhibitors.
- Negative feedback is an inverse response to change in environment e.g. when blood concentrations of **thyroid hormones** increase above a certain threshold, TRH-secreting neurons in the hypothalamus are inhibited and stop secreting TRH.



- Positive feedback involves a change in some variable that triggers mechanisms that amplify rather than reverse the change e.g. labor contractions during child birth

OSMOREGULATION

- The mechanism of regulation, generally between organism and its environment, of solute and the gain and loss of water is osmoregulation.
- Water is solvent of the solutes in the cell. Each cell has been adapted to defined quantity of water in relation to salts in it to perform its functions.

Water Relations to Cells

(i) Hypotonic Environment

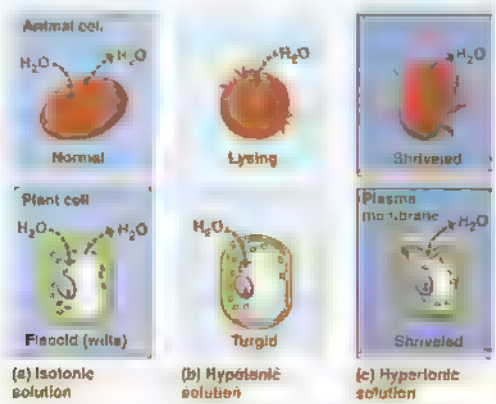
- A diluted solution compared to the cell concentration is designated as hypotonic environment.
- The hypotonic environment osmotically causes entry of water into the cell and renders the cell solutions diluted which need to be regulated.
- The plant cells become turgid while animal cells may be ruptured.

(ii) Hypertonic Environment

- The more concentrated external environment is termed as hypertonic environment.
- The hypertonic environment renders cell solutions concentrated and shrinks the cell due to loss of water which needs to be regulated.

(iii) Isotonic Environment

- Environment that resembles to internal solution is called isotonic environment.
- There is no need of osmoregulation in such case. Such animals are called osmoconformers.



OSMOREGULATION IN ANIMALS OF DIFFERENT ENVIRONMENT

Animal cells require more critical balance of water and solutes in the body as they cannot survive with a net water gain or loss. Water continuously enters and leaves the cells.

Approaches to Osmoregulation in Animals

There are two approaches in maintaining balance of water and solute.

(i) **Osmoconformers**

Animals that do not require adjustment of internal osmotic state are called osmoconformers.

In these animals, body fluids are kept isotonic to the external environment e.g. fishes of marine saltwater environment.

(ii) **Osmoregulators**

Animals whose body fluid concentrations differ noticeably with outside environment actively regulate to discharge the excess water in hypotonic and excrete salt in hypertonic are called osmoregulators.

- These animals discharge excess water in hypotonic conditions.
- They excrete salts in hypertonic conditions.

Osmoregulation in Different Environments

Osmoregulation has enabled the animals and plants to distribute themselves in wide range of habitats.

(1) **Osmoregulation in Marine Environment**

- Most marine invertebrates are osmoconformers.
- Among vertebrates, variety is present Some of the examples are described below.

(i) **Hagfishes** are isotonic with the surrounding sea water.

(ii) Most **cartilaginous fishes** maintain lower internal salt concentration than that of sea water. Their kidneys are involved in osmoregulation. They excrete salts through gills and also possess salt secreting organs such as rectal glands. Excretion of salts is by active transport.

(iii) Some fishes have low salt concentration and thus live in hypertonic sea water. To prevent excess entry of salty water in body, they retain urea in body fluids in form of **trimethylamine oxide** for protection against toxicity of urea.

(iv) Some of the bony fishes, which live in marine water, lose water from their hypotonic body fluids to hypertonic environment. They drink large amount of sea water and excrete concentrated urine resulting in maximum salt excretion and minimum water loss.

2) **Osmoregulation in Fresh Water Environment**

Fresh water animals are constantly facing the osmotic flooding of body fluids and loss of salts. Mechanism of osmoregulation in different fresh water animals is as follows

(i) Freshwater **protozoa**, amoeba and **paramecium** pump out excess water by structure contractile vacuoles.

(ii) Many freshwater animals including fishes remove excess water by producing large volume of very dilute urine.

(iii) Loss of salt in such animals is compensated by using salt containing food and active uptake of salts by gills and skin.

3) **Osmoregulation in Terrestrial Environment**

The evaporative loss of water leading to dehydration is the major problem for terrestrial life. Arthropods and vertebrates have successfully adapted to terrestrial mode of life. Different adaptations in terrestrial animals for osmoregulation are

(i) Terrestrial animals are covered either by **waxy exoskeleton** (insects) or **multi-layered dead keratinized** skin cells (vertebrate), which prevent loss of water.

(ii) Drinking and eating **moist foods** compensate the loss of water.

(iii) These animals have **metabolic and behavioral** adaptations.

(iv) Some desert animals feed on seeds of desert plants containing more carbohydrate, which produce **water of metabolism** e.g. kangaroo rat. They survive without drinking water.

(v) Terrestrial animals **reabsorb** moist filtered water through kidney during excretion and produce concentrated urine.

(vi) These animals can tolerate dehydration and it differs in various animals. This characteristic is known as **anhydrobiosis**.

NITROGEN CONTAINING EXCRETORY PRODUCTS

Excretory Products in Animals

Different excretory products of animals are;

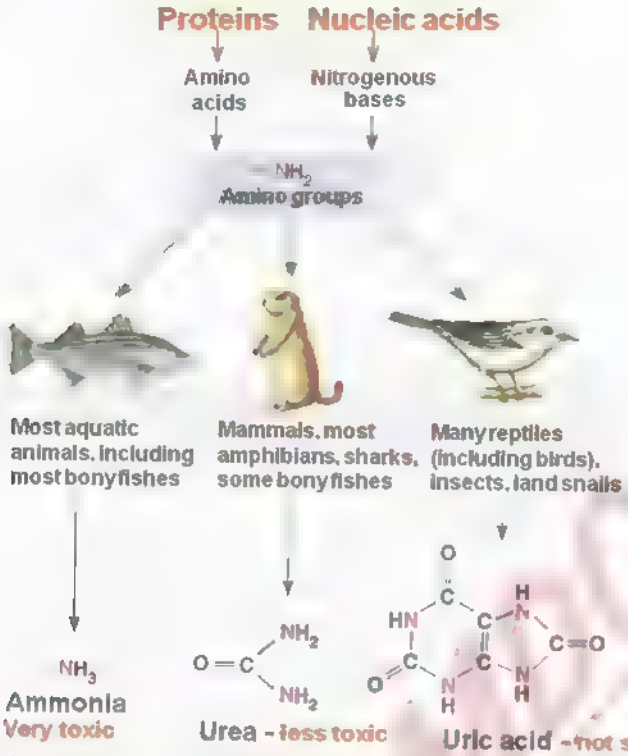
- **Water**, which is excretory product of animals living in hyperosmotic environment.
- **Salts**, which are excretory products of animals living in hypertonic environment.
- **Nitrogenous wastes**, which are main excretory products produced by breakdown of amino acids and nitrogenous bases or nitrogenous waste metabolites constitute the excretory product.
- **Deamination** is removal of amino group ($-NH_2$) from amino acids. This amino group cannot be stored or reused for recycling of amino acids.
- This amino group is dissolved in water and excreted in form of ammonia to avoid toxic rise in plasma or transferred to another molecule for removal or reuse.

Types of Nitrogenous Wastes

Nitrogenous wastes are mainly produced by catabolism of proteins, purines and pyrimidine bases present in nucleic acids.

- Nitrogen produced **from amino acids** is excreted mostly as ammonia, urea or uric acid and very small quantities as creatinine, creatine or trimethylamine oxide.
- Metabolism of **purine and pyrimidine** bases mostly produces significant amount of nitrogenous wastes of hypoxanthine, xanthine, uric acid, allantoin, urea and ammonia.

- Proteins
  - Excess → Ammonia, Urea, Uric Acid
  - Low Quantity → Creatine, Creatinine, Trimethylamine Oxide
- Nitrogenous Bases (Purines and Pyrimidine)
  - Excess Quantity → Ammonia, Urea, Uric Acid
  - Low Quantity → Hypoxanthine, Xanthine, Allantoin



Nature of Excretory Products in Relation to Habitats

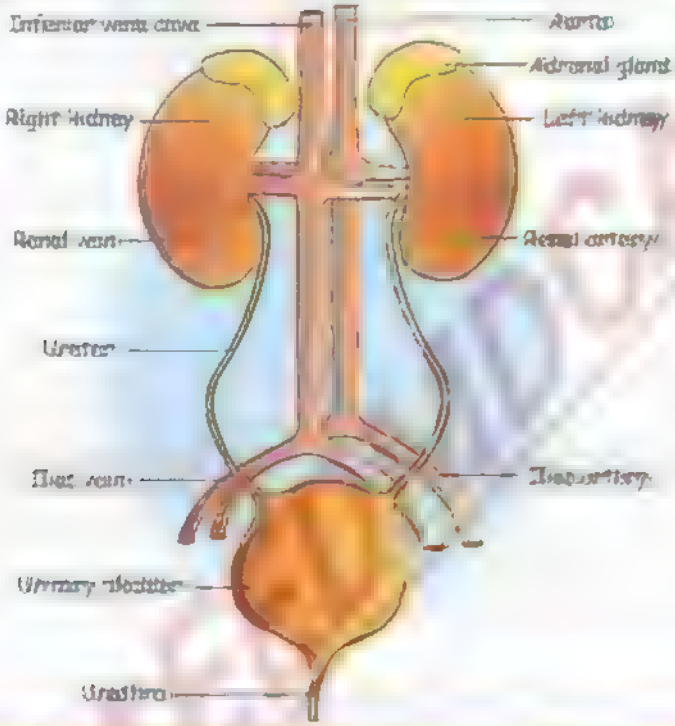
There are three main nitrogenous wastes, which are produced and excreted according to habitat. These are ammonia, urea and uric acid.

Habitat	Water Supply	Nitrogenous Waste	Toxicity	Amount of Water/1g	Name with Respect to Waste	Examples
Aquatic	Maximum	Ammonia	Most toxic	500ml/1gN	Ammonotelic	Hydra, planaria
Terrestrial	Moderate	Urea	Moderate toxic	50ml/1gN	Ureotelic	Human
Terrestrial	Minimum	Uric acid	Less toxic	1ml/1gN	Uricotelic	Reptiles, birds

EXCRETORY HOMEOSTASIS

- Excretory system of humans includes both **liver and kidneys**.
- Liver is involved in production of nitrogenous wastes (e.g. urea) while kidneys filter urea from blood and remove it outside the body in form of urine.
- Urinary system in humans is specialized for formation of urine and its removal outside the body. This urinary system includes **kidneys and associated tubules like ureters, urinary bladder and urethra**.
- Following filtration of blood and further processing through tubular system, urine is collected in the central cavity of the kidney called renal pelvis. Pelvis is proximal enlarged end of ureter.
- Urine leaves the kidney through a duct called ureter.

- Ureters of both kidneys drain into urinary bladder through uretral orifice. Urinary bladder stores urine before its removal.
- Urine leaves the body during urination/micturition, from the bladder through a tube called the urethra.
- Urethra empties near vagina in females or through penis in males.
- Sphincter muscles (Urethral sphincter) near the junction of urethra and urinary bladder control the urine in bladder. This is an example of dual sphincter.



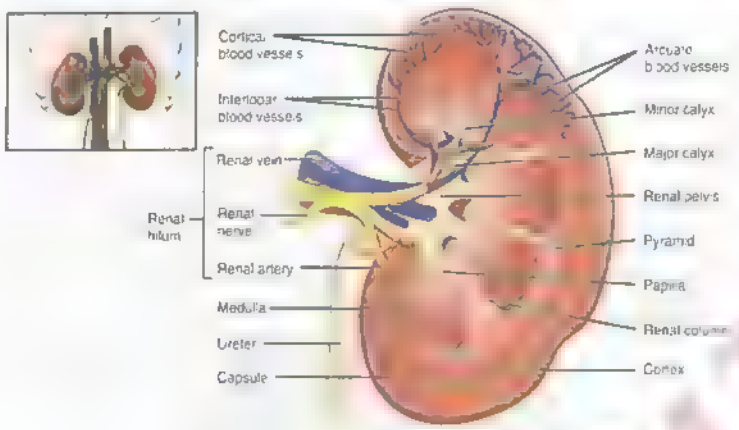
[illegible] OF KIDNEYS

Introduction

- Humans have **two kidneys placed in abdominal cavity**, on both sides of vertebral column and attached with dorsal abdominal wall.
- Right kidney is slightly lower in position than left kidney due to longer right lobe of liver.
- A pair of kidneys consists of millions of functional units called nephrons or urinary tubules
- Kidneys are not only the major excretory organs of humans but also **act as an osmoregulatory organ.**
- Kidneys account for less than **1%** of the body weight, while they receive **20%** of blood supplied with each cardiac output.

Morphology

- Kidneys are **bean shaped** with inner concave and outer convex walls.
- Middle portion of kidneys by which all vessels enter, or leave is called **renal hilus.**
- Outer darker portion of kidney is called **renal cortex** while inner brighter portion is called **renal medulla.** Cortex contains renal corpuscles and convoluted tubules.
- **Renal pyramids** are conical parts of renal medulla containing blood vessels and collecting ducts. All the pyramids project into the pelvis.



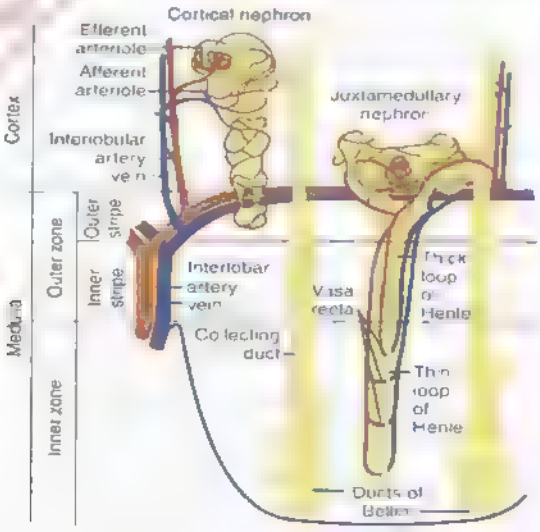
Functions

- Kidneys are involved in **filtration of wastes from blood**, formation of urine and its removal outside the body through tubular system.
- Kidneys act as **osmoregulatory organs** and maintain solute and water level in blood and body.
- Kidneys also help to **regulate blood volume and blood pressure**.
- Kidneys also release a stimulus (erythropoietin) for **production of RBCs**.

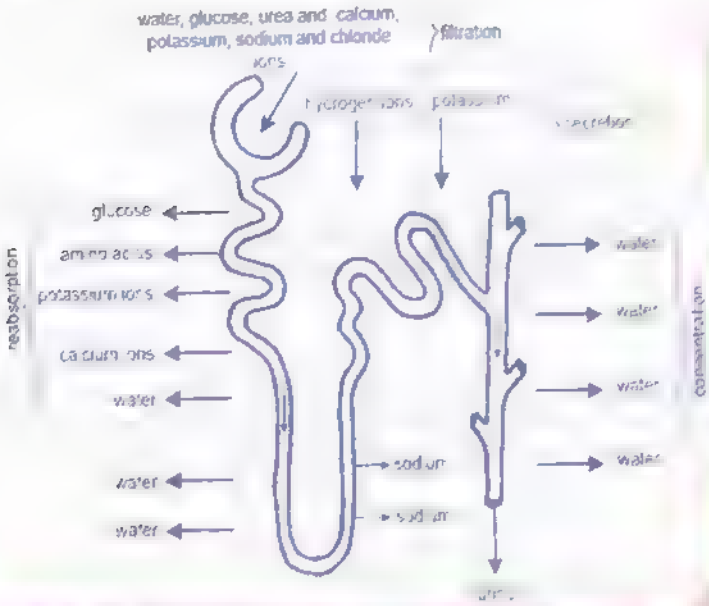
- Basic structural and functional unit of a kidney is called **nephron**.
- These are also called as **urinary tubules**.
- Each nephron is composed of **renal corpuscle** and renal tubule.

Types

- Nephrons are of two types i.e. **cortical and juxtamedullary**.
- Those nephrons that are present along the border of cortex and medulla, with tubular system looping deep in inner medulla are called juxtamedullary nephrons.
- The nephrons arranged along the cortex are called cortical nephrons.
- **Juxtamedullary nephrons** play important role in production of concentrated urine.



Structure and Functioning



POINT TO PONDER

Which kidney is slightl
than other in positio

POINT TO PONDER

Which organ in

POINT TO PONDER

Component		
Bowman's capsule	• Cup shaped • Blind end	Pressure Filtration
Glomerulus	• Cluster of blood capillaries inside Bowman's capsule • Porous walls • High blood pressure • Receives blood from afferent arterioles.	Pressure Filtration
Peri-tubular network	• Network of capillaries around tubular part • Receives blood from efferent arterioles • Vasa recta is additional loop in Juxtamedullary nephrons	Selective Reabsorption
Proximal convoluted part	• 1st convoluted part	• Selective Reabsorption • Maximum Reabsorption
Loop of Henle	• Descending/ Thin limb (Permeable to water) • Ascending/ Thick limb (Permeable to Na^+ ions)	• Selective Reabsorption • Counter Current Multiplier • Site of action of aldosterone • Tubular Secretion (Ascending Limb)
Distal convoluted part	2nd convoluted part	• Selective secretion
Collecting tubules	Changeable permeability for water	Reabsorption of water under action of ADH

Mechanism of Urine Formation

Urine formation involves following steps:

(i) **Pressure Filtration/ Ultrafiltration**

- Blood passing through glomerulus is filtered into Bowman's capsule.
- Glomerulus walls are porous and the fraction of blood pressure reaching here provides the filtration pressure.
- The filtrate appearing in Bowman's capsule is called as glomerular filtrate, which contains various useful substances such as glucose, amino acids, salts etc.
- Composition of glomerular filtrate is same as plasma minus plasma proteins.

(ii) **Selective Reabsorption**

- It occurs at the tubular part of nephrons.
- Most of the useful constituents of glomerular filtrate (80%) are reabsorbed in proximal tubules and when filtrate leaves proximal tubules, it mostly contains nitrogenous wastes.
- Glucose, amino acids, vitamins and hormones are 100% reabsorbed while sodium chloride and water are 80% reabsorbed.

(iii) **Tubular Secretion**

- The tubular epithelium also secretes substances into the lumen.
- This secretion is very selective and is mainly of hydrogen ions to balance pH/ acid base balance of blood and filtrate.

Concentration of Urine

- In restricted supply of water, the conservation of water is the principal function of the body. This is done by concentration of filtrate by counter current and hormonal mechanisms.
  Less H_2O/ Hyperosmotic Body Fluid → More ADH → More Reabsorption of H_2O → Less amount of concentrated urine.
- In the sufficient or excess supply of water, reabsorption of water from the filtrate is reduced, specifically due to inhibition of release of ADH in the presence of hypo-osmotic body fluids. The reduction in reabsorption causes large volume of diluted urine.
  More H_2O/ Hypo-osmotic Body Fluids → Less ADH → Less Reabsorption of H_2O → More amount of diluted urine
- Mammalian kidney including humans is adapted to conserve water by over **99.5% reabsorption of glomerular filtrate.**

Factors Involved in the Formation of Concentration Urine

(i) **Structural Adaptation**

Juxtamedullary nephrons and vasa recta are structural adaptations for concentration of urine.

(ii) **Hypertonic Environment of Medulla**

The interstitial fluid of kidney is gradually concentrated from cortical to medullary part. Thus, inner medulla is highly concentrated due to presence of urea and counter current multiplier.

(iii) **Counter Current Multiplier**

Counter current multiplier causes gradual osmotic outflow of water from the filtrate back to kidney as it passes downward in the descending loop of Henle. Ascending loop of Henle does not allow outflow of water from its filtrate, instead actively transports Na^+ into kidney interstitum to sustain its high concentration.

(iv) Hormonal Control

- The active uptake of Na^+ in the ascending limb or thick loop of Henle is promoted by the action of **aldosterone**, the hormone secreted from adrenal cortex.
- **ADH** released from posterior pituitary lobe acts to actively transport water from filtrate in collecting tubules back to kidney.

POINT TO PONDER

RENAL DISORDERS

Kidney stones

- Stone formation in kidney and urinary bladder, results in obstruction to flow of urine, increases susceptibility to infection and thus eventually leads to kidney failure.

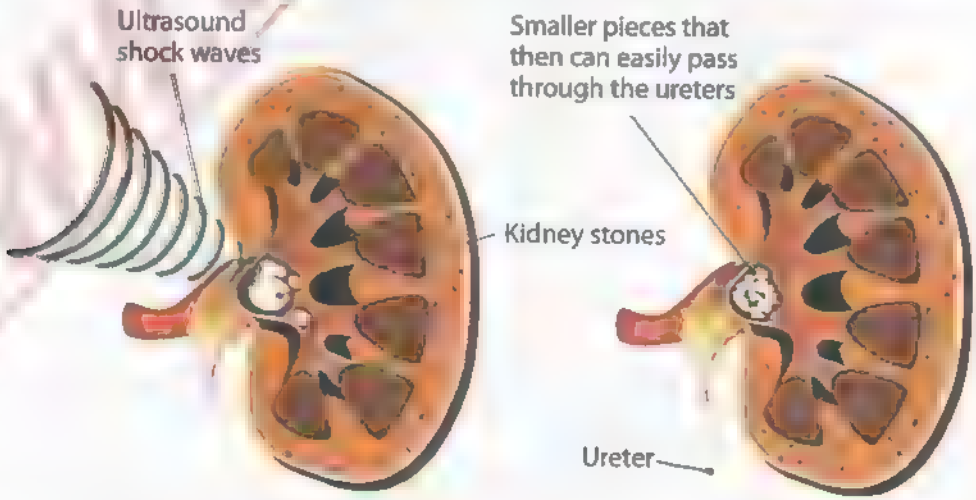
Types of Stones

- Different types of kidney stones are as follows:

Calcium oxalate	70%	• Higher level of oxalates in blood. • Increased use of tomatoes and green leafy vegetables.
Calcium phosphate	15%	• Hypercalcemia (high level of Ca^{2+} in the blood) • Hyperparathyroidism
Uric acid	10%	• Increased uric acid level in blood • High protein intake in food

Cure

- **Lithotripsy** is applied for smaller stones.
- Lithotripsy is used for non-surgical removal of kidney stones.
- **Extracorporeal shock wave lithotripsy (ESWL)** is the one opted for small kidney stones. This is a minimal invasive surgery, in which kidney, pelvic or ureteric stones are broken down by bombarding ultrasounds or X- rays on them without giving any cut.
- Smaller stone pieces are flushed through ureter and then through urethra out of the body.
- **Renal surgery** is done for larger stones which can't be broken by lithotripsy technique. Direct surgical exposure and removal of stone is done.



Renal Failure

- Failure of all the kidney functions i.e., excretory, osmoregulatory, hormonal (secretion of erythropoietin) and metabolic function is called renal failure.
- Nephrons are destroyed particularly at glomerular part, leading to accumulation of urea, other waste materials, bone weakening and anemia.

Causes

- Acute renal failure can occur due to blood clot or cholesterol deposits. Certain chemotherapy drugs, antibiotics and toxins such as alcohol, heavy metals and cocaine can also cause kidney failure.
- Most common causes of chronic renal failure are diabetes and hypertension. Other causes include long-term daily use of anti-inflammatory drugs and other analgesic medicines.

Cure

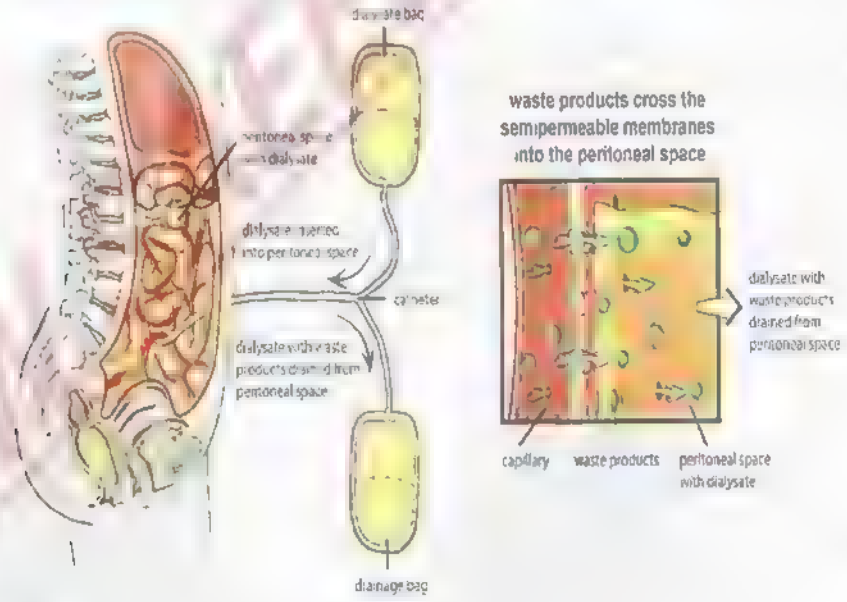
It is either dialysis or kidney transplantation.

Dialysis

- The process of artificially removing nitrogenous wastes is called dialysis.
- The waste materials e.g. urea from the blood, either by pass kidneys through an artificial kidney (dialysis machine) or filtering it within the abdomen.
- Dialysis is of two types i.e. peritoneal dialysis and hemodialysis.

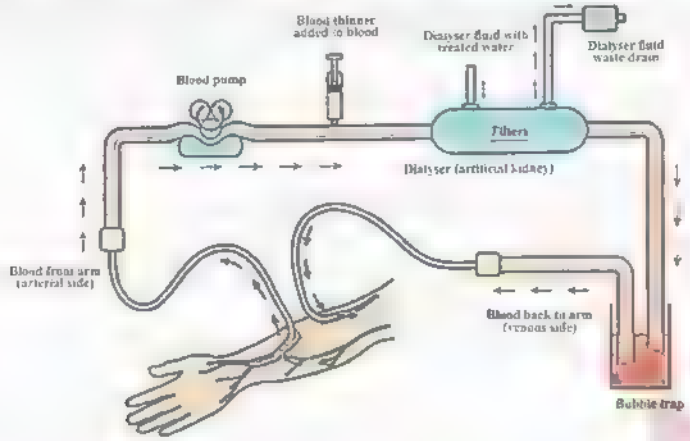
(i) Peritoneal Dialysis

- **Peritoneal dialysis** uses the peritoneum (inner lining of abdomen) to filter the blood present in peritoneal blood vessels.
- Peritoneal cavity is filled with dialyzing solution. Waste materials having high concentration in blood are filtered through peritoneum into the peritoneal cavity containing dialyzing solution, which is removed afterwards.



(ii) Hemodialysis

- Hemodialysis means cleaning the blood.
- Waste material in blood is filtered by passing it through a machine which contains a dialyzer also called **artificial kidney.**
- It is made of two spaces separated by a thin membrane. Blood flows inside the membrane in one direction and dialyzing fluid outside the membrane in another direction.



POINT TO PONDER

high blood pressure?

POINT TO PONDER

(e) Excretion

Renal Transplant

- It is considered permanent treatment. Since dialysis can only be done on temporary basis.
- Mostly opted in severe renal failure, called uremia or end-stage renal disease
- Only a matched kidney (blood/HLAs and tissue matching) can be transplanted in an individual. So it needs donor-recipient matching

ILLUSTRATIONS AND LABELLED DIAGRAMS ON THERMOREGULATION

- Maintenance of internal temperature within a tolerable range is designated as thermoregulation.
- Animals are classified into three groups on the base of thermoregulation i.e. ectotherm, endotherm and heterotherm.
- Animals that generate their own heat through heat production as by product during metabolism are endotherms e g. humans, birds, some fishes and flying insects.
- Animals which produce metabolic heat at low level (that is also exchanged with the environment quickly) and absorb heat from surroundings are called ectotherms e.g. most invertebrates, fish, amphibians and reptiles.
- Animals which are capable of varying degrees of endothermic heat production but generally do not regulate their body temperature within a narrow range are heterotherms e.g. bats, humming bird etc.

Thermoregulatory Adaptations in Animals

Adaptation	Examples
Structural Adaptations	• Changes in sub-dermal fatty layer insulation. • Pelage • Sweat glands • Lungs modification for panting
Physiological Adaptations	• Regulation of blood flow to skin (Vasodilatation, Vasoconstriction). • Activation of muscles for thermogenesis • Plumage fluffing • Activation of sweat glands for evaporative cooling
Behavioral Adaptations	• Change in habitat • Change in body posture

THERMOREGULATION IN HUMANS

Regulatory Strategies

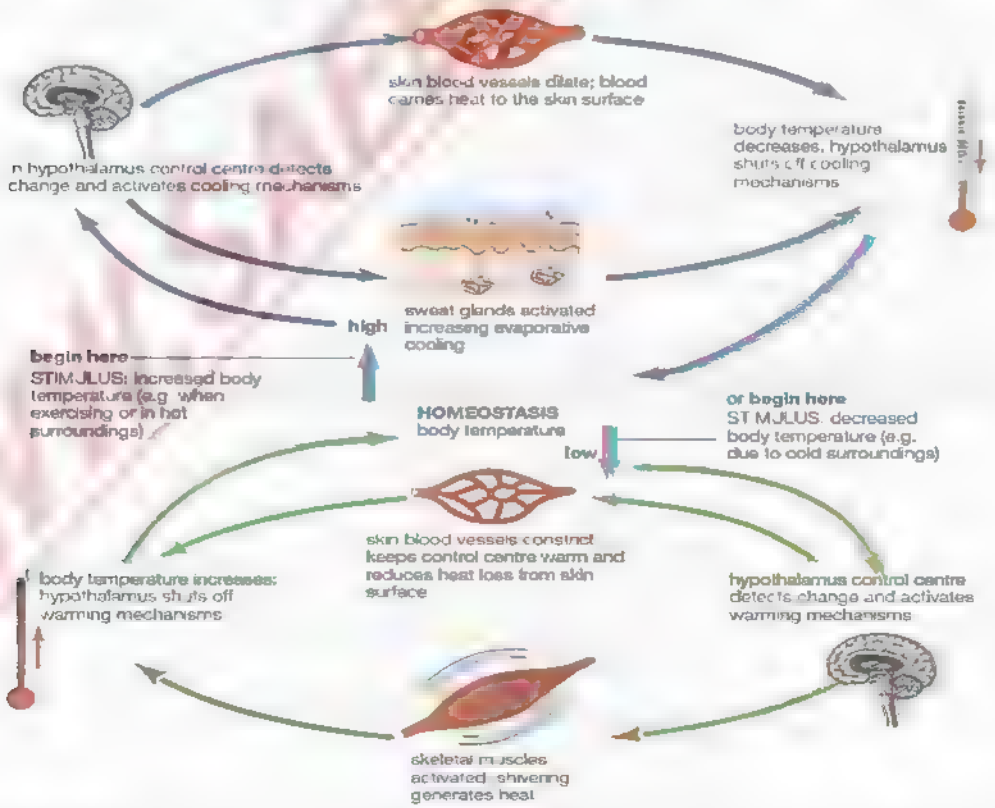
- Mammals including humans maintain their body temperature within a narrow range of about 36-38°C (36.1-37.8°C).
- Humans are endotherm.
- Hypothalamus is thermoregulatory centre in humans.

Strategies in Cold Temperature

- The rate of heat production is increased by increased muscle contraction by movements or shivering so called shivering thermogenesis.
- Hormones trigger the heat production as do thyroid hormones and are termed as non-shivering thermogenesis.
- Some mammals have brown fat, which is specialized for rapid heat production.
- Vasoconstriction occurs at skin which reduces rate of blood flow and also heat loss.
- Vasodilatation occurs at trunk where most of the vital organs are located.
- Sweat glands are inhibited.
- Erection of hair in humans and rising of fur in others maintains body heat by trapping air and increasing insulation.
- Humans mostly rely on a layer of fat beneath skin acting as insulating layer. Similarly, marine mammals like whales and seals inhabit much colder water and have a thick layer of insulating fat called blubber just under the skin.

Strategies in Warm Temperature

- Vasodilatation occurs at skin which increases rate of blood flow and more heat loss.
- Heat dissipation occurs either through evaporation, radiation, conduction or convection.
- Sweat glands are activated which promote evaporative cooling. In some mammals, this evaporative cooling occurs in the respiratory tract (panting in dogs) or through saliva and urine (as in bats).



TOPIC-12 » SUPPORT & MOVEMENT

COURSE CONTENT

- Human Skeleton (Bone and Cartilage)
- Axial Skeleton
- Appendicular Skeleton
- Disorders of Human Skeleton
- Bone Fractures
- Joints
- Joint Injuries
- Comparison of Muscle Types
- Structure and Ultra-Structure of Skeletal Muscles
- Sliding Filament Model and Energy for Muscle Contraction
- Muscle Disorders

HUMAN SKELETON (BONE AND CARTILAGE)

Bone

- It is the most rigid form of connective tissue and forms endoskeleton of humans.
- The collagen fibers of bones are hardened by calcium phosphate deposition

Types of Bone

Feature	Compact Bone	Spongy Bone
Nature	Dense and strong	Light and highly porous
Blood supply	Less	More
Function	Attachment site for muscles	Contains bone marrow and involved in blood cell production.
Example	Outer portion of long bones	Inner portion of long bones

Bone Cells:

- **Osteoblasts:** Bone forming cells
- **Osteocytes:** Mature bone cells
- **Osteoclasts:** Bone dissolving cells

Bone Development:

Bone replaces cartilage in early development.
Osteoclasts invade and dissolve the cartilage → Osteoblasts then replace it with bone → Matrix is hardened by calcium phosphate deposition →Osteoblasts are gradually entrapped within it (now called Osteocytes).

Cartilage

- It is much softer connective tissue than bone.

- It has no blood supply and gets nutrients by diffusion.
- Living cells of cartilage are called chondrocytes.
- Collagen matrix is secreted by chondrocytes.

Types of Cartilage

(i) Hyaline Cartilage

- Most abundant type in human body
- Found at the movable joints

(ii) Elastic Cartilage

- Matrix containing bundles of collagen fibres
- Forms external ear/ pinnae and the epiglottis

(iii) Fibrocartilage

- Annulus fibrosus of vertebral disc is an example.

Cells	Mature cells are osteocytes	Mature cells are chondrocytes
Strengthening Material	Inorganic salts	No
Reshaping	✓	×
Blood Supply	✓	×
Healing	✓	×

Tendon and Ligament

Nature	Inelastic connective tissue	Elastic connective tissue
Function	Attaches muscle to bone	Holds bones at joints

- Human skeleton is mainly bony. There are about 350 bones in infant and 206 in adult.
- Human skeleton is generally divided into two parts. axial skeleton (80 bones) and appendicular skeleton (126 bones).
- Axial skeleton provides basic framework of body and consists of skull, vertebrae and ribs.
- Appendicular skeleton is associated with extremities and consists of pectoral girdle with forelimbs and pelvic girdle with hind limbs.
- Primary function of skull is protection of brain.
- Vertebral column provides protection to spinal cord. It has four curvatures.

	Sub-parts	Bones
Axial Skeleton		
Skull (22)	Cranium (8)	• Paired (2): Parietal & Temporal • Unpaired (4): Frontal, Occipital, Sphenoid, Ethmoid.
	Face (14)	• Paired (6): Maxilla, Zygomatic, Nasal, Lacrimal, Palatine, Inferior Concha. • Unpaired (2): Mandible, Vomer
Vertebral Column (33 vertebrae)	Cervical	7 vertebrae, neck region, first two atlas and axis
	Thoracic	12 vertebrae
	Lumbar	5 vertebrae
	Pelvic	9 vertebrae, anterior 5 join to form sacrum & posterior 4 join to form coccyx (tail bone).

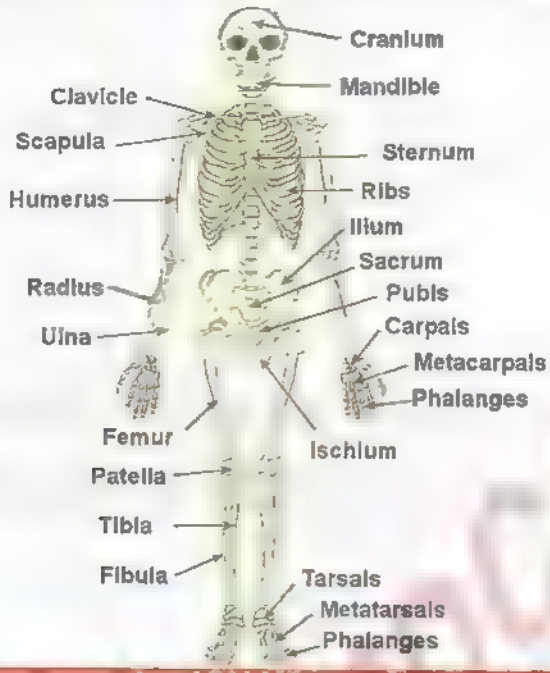
Rib cage and sternum (Chest bone)	12 pairs of ribs	• 12 pairs articulate with thoracic vertebrae posteriorly. • 7 pairs connect anteriorly with sternum directly (True ribs) • 3 pairs connect with sternum through costal cartilages (False ribs). • 2 pairs are of floating ribs (since they don't attach to the sternum).

APPENDICULAR SKELETON

Pectoral Girdles (4)	• Scapula (Shoulder blade) • Clavicle (Collar bone/ Beauty bone) connects scapula with sternum.
Fore limb (30×2)	• 1 Humerus (Upper arm) • 1 Radius and1 ulna (Forearm) • 8 carpals (Wrist) • 5 metacarpals (Palm) • 14 phalanges (Fingers/ Digits)
Pelvic Girdle (2)	• 2 coxal (hip) bones • Each having ilium, ischium and pubis
Hind limb (30×2)	• 1 Femur (Upper leg) • 1 tibia and1 fibula (Lower leg) • 7 tarsals (Heel) • 5 Meta-tarsals (Sole) • 14 Phalanges (Digits/ Toes) • 1 Patella (Knee cap)

Joints of Skeleton

Joint		Formation
Shoulder Joint	Ball and Socket Joint	Head of humerus and glenoid cavity of scapula
Elbow Joint	Hinge Joint	Distal end of humerus and proximal ends of radius & ulna
Wrist Joint	Multistage Joint	Distal ends of radius and ulna and carpals
Hip Joint	Ball and Socket Joint	Head of femur and acetabulum of hip bone
Knee Joint	Hinge Joint	Distal end of femur and proximal ends of tibia & fibula
Ankle Joint	Multistage Joint	Distal ends of tibia and fibula and tarsals



DISORDERS OF HUMAN SKELETON

Disc Slip

- Sudden physical trauma like bending forward while lifting a heavy weight results in herniation of disc.
- Protrusion of nucleus pulposus. May result in compression of spinal cord or any nerve root.
- Disc slip is treated with bed rest, traction and analgesics as a pain killer. If fails, the disc is removed surgically.

Spondylosis

- It is a form of arthritis in which there is immobility and fusion of vertebral joints.
- A spondylotic vertebrae is called Bamboo spine, since its same as an elongated upright bamboo stem.

Sciatica

- It is a stabbing pain radiating along the course of sciatic nerve in the leg.
- Fall, herniated disc, improper buttock injection.
- If just compressed result in excruciating pain in the leg, but if transected leads to complete.
- Paralysis of that leg.
- Recovery is usually slow and incomplete.

Arthritis

- Inflammatory or degenerative disease damaging joints. Membrane lining the joint thickens; fluid protection is lost, resulting in loss of friction.
- Arthritis means inflammation of joints.
- Acute form caused by bacterial invasion, and treated with antibiotics.
- Chronic are mostly genetic in origin including osteoarthritis, rheumatoid arthritis and gouty arthritis.
- Osteoarthritis is a disease of synovial joints, characterized by cartilage loss. Genes responsible for synthesis of collagen type II are defected.
- Rheumatoid arthritis is symmetrical polyarthritis of unexplained cause.

Fracture

Break in the continuity of a bone is called a fracture.

Treatment

Fracture repair comprises of reduction, fixation in realigned position and immobilization

Reduction

Fractured segments are returned to their original position.

Closed:

Bone ends are returned back at their normal position manually.

Open:

Surgery is performed to return the broken ends to their original position.

Fixation

Reduced segments are fixed both by open and closed techniques.

Immobilization

Immobilization of fractured bone is done via a cast or by traction. It is necessary for proper healing.

The Process of Healing and Repair

Ideal healing time is 8 – 12 weeks, but is longer in the presence of infection, poor health and diet, in weight bearing bones, and in bone with poor blood supply (e.g., of an elderly individual).

There are four phases of repair:

Hematoma Formation

- A mass of a clotted blood at the fracture site.
- Comes from torn blood vessels of the bone and in its surrounding
- Contains substances like bone morphogenic proteins (BMP), which help in healing process.

Soft Callus Formation

- It is formed within 3- 4 weeks
- Capillaries grow in hematoma and remove debris.
- Fibroblast and osteoblasts migrate and construct a bone called soft callus.

Bony Callus

- By osteoblasts and osteoclasts.
- Begin 3- 4 weeks after injury, up to firm bone formation i.e., within 2- 3 months.

Remodeling

- By osteoclasts.
- Excess bony callus on the outside is removed.

- Joints occur where bones meet.
- They not only hold our skeleton together but also give it mobility.

Classification of Joints

On Base of Amount of Movement

(i) Immovable Joints

- These joints do not allow any movement.
- Fibrous joints are immovable joints.
- Sutures (Joints of skull) are examples.

POINT TO PONDER

human Adult

(ii) Slightly Moveable Joints
- These joints allow slight movements.
- Cartilaginous joints of vertebral column are examples.

(iii) Freely Movable Joints
- These joints allow free movements.
- Synovial joints are examples of freely moveable joints.

On Base of Structure

(i) **Fibrous Joints**
- These joints held together by short fibres embedded in connective tissue.
- These joints are immovable.
- Examples of fibrous joints are joints between skull bones and joints between teeth and jaws.

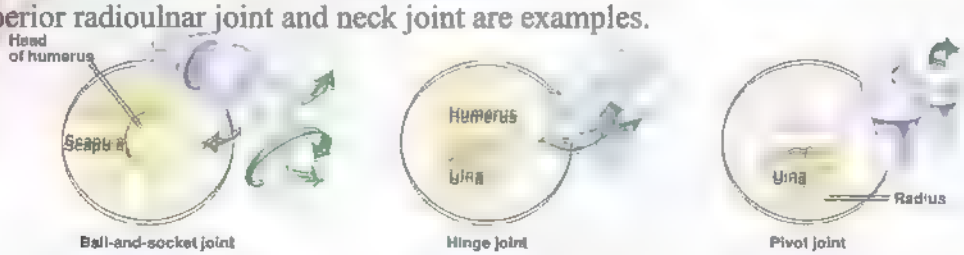
(ii) **Cartilaginous Joints**
- These allow little or no movement.
- Hyaline cartilage forms joint between growing bones.
- Fibrous cartilage found between vertebrae at the point where coxal bones meet in front of the pelvis.

(iii) **Synovial Joints**
- These joints contain a cavity filled with fluid and are adapted to reduce friction between moving joint.
- The joint is surrounded by a layer of connective tissue called fibrous capsule and inner layer of synovial membrane.
- Some parts of the capsule may be modified to form distinct ligament, holding the bones together.
- Synovial joints are further classified into following categories.

(i) **Hinge Joint**
- These joints allow movements in two directions.
- Pair of muscles is arranged in the same plane as that of joints. One end of muscle (origin) is fixed to immovable bone and other (insertion) to movable bone across the joint.
- Elbow and knee joints are examples.

(ii) **Ball & Socket Joint**
- These joints allow movements in several directions.
- Such joints have at least two pairs of muscles present perpendicular to each other.
- They provide maximum flexibility.
- Hip joint and shoulder joint are examples.

(iii) **Pivot Joint**
- These joints allow rotation within limits.
- Superior radioulnar joint and neck joint are examples.



JOINT INJURIES

Torsion or sudden impact to the joint can be devastating. We will discuss here dislocation and sprain

Dislocation of joints

- A dislocated joint is a joint that slips out of the space.
- It occurs when ends of the bones are forced from their normal positions.
- A severe dislocation can cause tearing of muscles, ligaments and tendons that support the joint.
- Symptoms include; swelling, intense pain, and immobility of the affected joint
- The most common causes are a below, fall, or other trauma to the joint. In some cases, dislocations are caused by a disease or a defective ligament.
- Rheumatoid arthritis can also cause joint dislocation.
- A dislocated joint usually can only be needed to repair or tighten stretched ligaments.

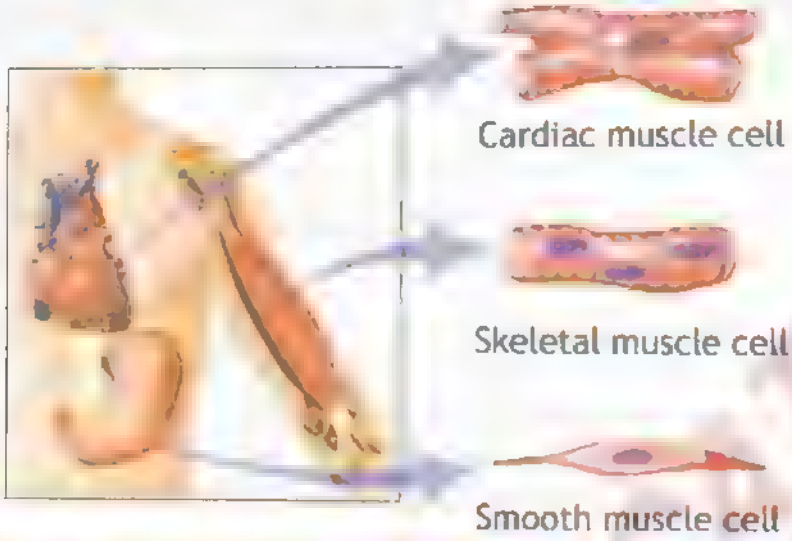
Sprain

- A sprain is an injury to a ligament.
- Commonly injured ligaments are in the ankle, knee and wrist.
- The ligament can be injured by being stretched too far from their normal position.
- The sprain should be rested. Sprains can usually be treated conservatively with treatments such as icing and physical therapy. Dressings, bandages or ace-wraps should be used to immobilize the sprain and provide support.

COMPARISON OF MUSCLE TYPES

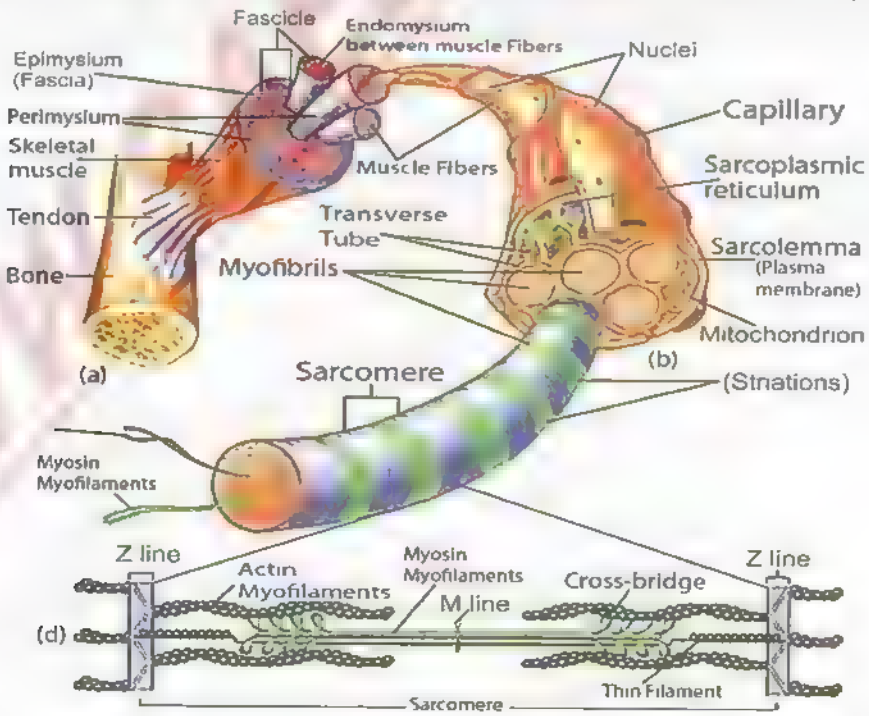
- Earliest forms of muscles to be evolved are smooth muscles which are present throughout animal kingdom.
- Cardiac muscles and skeletal muscles are found only in vertebrates.
- Most abundant type of muscles in human body are skeletal muscles.

		Cardiac	Skeletal
Muscle appearance	Unstriped (non-striated)	Irregular stripes (striated)	Regular stripes (striated)
Cell shape	Spindle	Branched	Spindle or cylindrical
Number of nuclei	One per cell	One per cell.	Many per cell
Speed of contraction	Slow	Intermediate	Slow to rapid
Fatigue	Vary	Never fatigue	Can be fatigued
Contraction caused by	Spontaneous, stretch, nervous system, hormones	Spontaneous	Nervous system
Function	Controls movement of substances through hollow organs	Pumps blood	Moves the skeleton
Control	Autonomic (involuntary)	Involuntary	Voluntary
Location.	Blood vessels, GIT, other hollow organs	Heart	Associated with skeleton



STRUCTURE AND ULTRA-STRUCTURE OF SKELETAL MUSCLE

- The muscles that are **attached to the skeleton** and are associated with the movement of bones are called skeletal muscles.
- The skeletal muscles are consciously controlled and therefore, are called **voluntary muscles**.
- Generally, each end of the entire muscle is attached to bone by a bundle of collagen, non-elastic fibers known as **tendons**.
- The entire muscle is covered by a layer of connective tissue called **epimysium**.
- Structural scheme of a skeletal muscle is given below:
  Skeletal muscles → Muscle bundles → Muscle fibers → Myofibrils → Sarcomere (smallest contractile unit of muscle fiber) → Myofilaments (Actin and Myosin).



Muscle Bundle

- Muscles bundles are also called as **muscle fasciculi**.
- These are bounded by a connective tissue called **perimysium**.
- Muscle bundles are further composed of muscle fibers or cells.

Muscle Fibers

- Each muscle fiber is a **long cylindrical cell** with **multiple oval nuclei** arranged just beneath its sarcolemma.
- Skeletal muscle fibers are huge cells.
- Their diameter is **10-100 µm**.
- Sarcoplasm of the muscle fiber is similar to the cytoplasm of other cells, but it contains usually large amount of **stored glycogen** and unique oxygen binding protein, **myoglobin**.
- Sarcoplasmic reticulum is continuous system of sarco-tubules extending throughout the sarcoplasm around each myofibril. It is like endoplasmic reticulum but devoid of ribosomes.
- Each muscle fiber further contains large number of myofibrils.

Myofibrils

- Each myofibril is **1-2 µm** that run in parallel fashion and extend entire length of cell.
- Bundles of these fibrils are enclosed by the sarcolemma.
- The myofibrils consist of smaller contractile units called **sarcomere**.
- Myofibril has **series of dark and light bands**. These give cell as whole its striped appearance.

Ultra-structure of Myofilaments

- Myofilament is made up of thick and thin filament.

(i) Thick Filament

- Thick filament is about **16nm in diameter** and is **composed of myosin**.
- Each myosin molecule has a tail terminating in two globular heads.
- Myosin tail consists of two long polypeptide chains coiled round each other.
- The heads are sometimes called **cross bridges** because they link the thick and thin myofilaments together during contraction.
- Each myosin filament is surrounded by six actin filaments on each end.

(ii) Thin Filaments

- Thin filaments are **7-8 nm thick** and are composed of chiefly **actin molecules**.
- The actin molecules are arranged in two chains which twist around each other like a twisted double strand of pearls.
- Twisting around the actin chains are two strands of another protein, **tropomyosin**. When the muscle is at rest, the tropomyosin is disposed in such a way that it covers the sites on the actin chain where head of myosin become attached.
- The other major protein in thin filament is **troponin**. It is actually three polypeptide complexes, one binds to actin, another bind to tropomyosin while third binds with calcium ions.

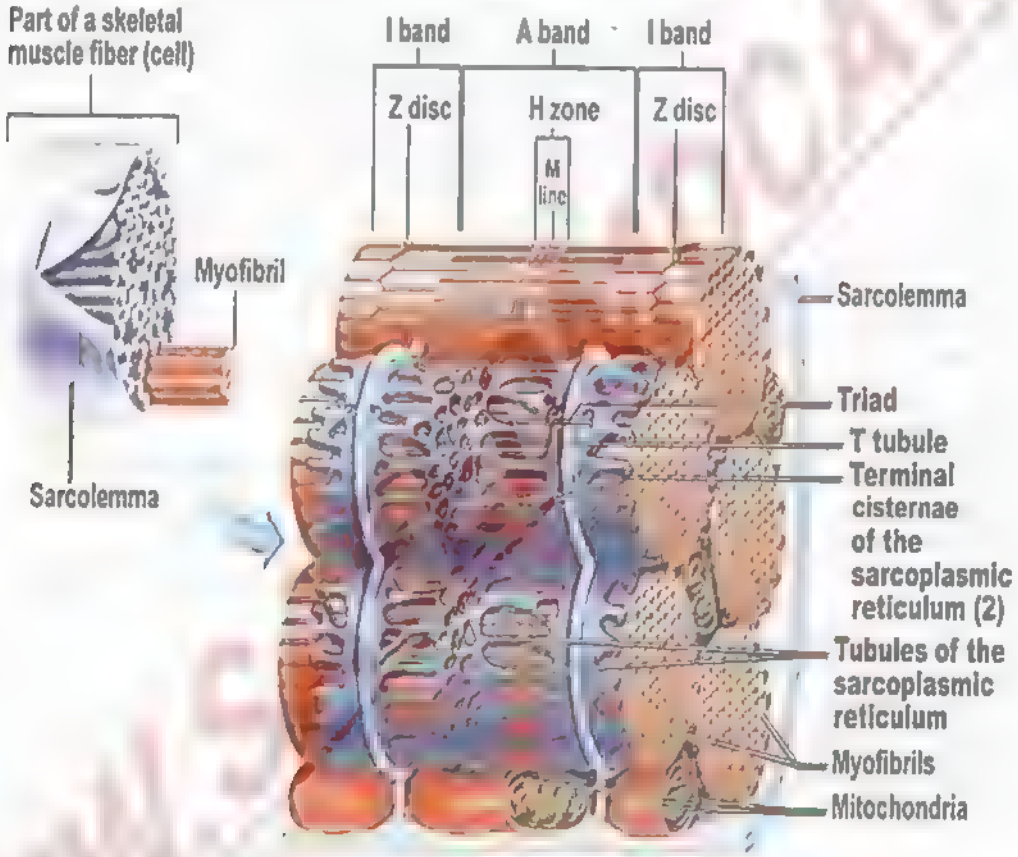
Banding Pattern

- Each dark band is called **A-band**; because it is anisotropic i.e. it **can polarize visible light**.
- The light band called **I-band** is isotropic or **non-polarizing**.
- Each A-band has a lighter strip in its mid-section called **H-zone**.
- The H-zone is bisected by dark line called **M-line**.

- The I-bands have mid line called **Z-line**.
- A sarcomere is the region of a myofibril between two successive Z lines and is the smallest contractile unit of muscle fiber.

T-Tubule, T System & Triad

- The sarcolemma of muscle fiber cell penetrates deep into the cell to form hollow elongated tube, the transverse tubule or T-tubule, the lumen of which is continuous with the extracellular fluid.
- The thousands of T-tubules of each muscle cell are collectively called **T-system**.
- It extends and encircles the myofibril at the level of Z-line or A-I junction.
- The T-tubule and the terminal portion of the adjacent envelope of sarcoplasmic reticulum form triads at regular interval along the length of the fibril.



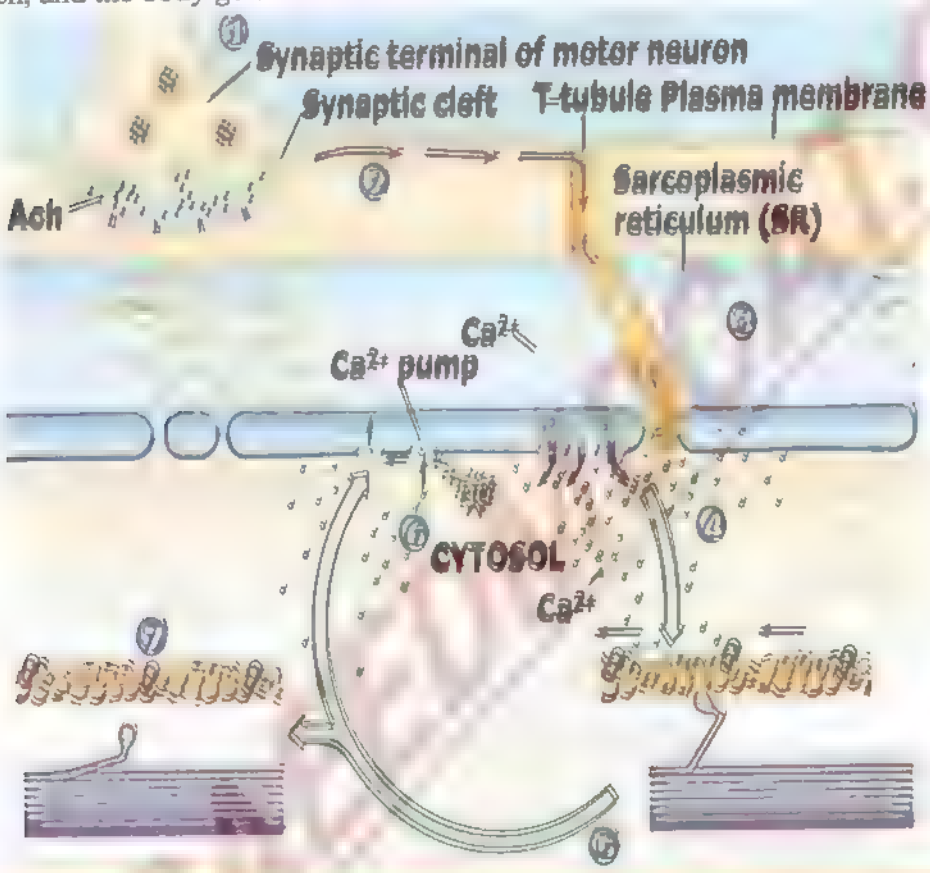
Initiation of Muscle Contraction

- Muscle contraction is initiated by nerve impulse arriving at the **neuromuscular junction**. All the fibers innervated by a single motor neuron are a "**motor unit**" and contract **simultaneously**.
- Nerve impulse from sarcolemma penetrates into the muscle fiber through T-tubule.
- Then it is carried through the T-tubule to the adjacent SR.
- The **calcium gates** of SR open releasing calcium in cytosol.
- Calcium ions bind with the troponin molecules of thin filaments. This has the effect of

POINT TO PONDER

displacing the tropomyosin and exposing the binding sites for the myosin.

- Once the myosin head has become attached to the actin filament, ATP is hydrolyzed and the bridges goes to its cycle and result in muscle contraction.
- **Rigor Mortis** is stiffening of the body after death. Since ATP is required to break the bond between actin and myosin, which get deficient after death, thus the bridges can't be broken, and the body gets stiff.



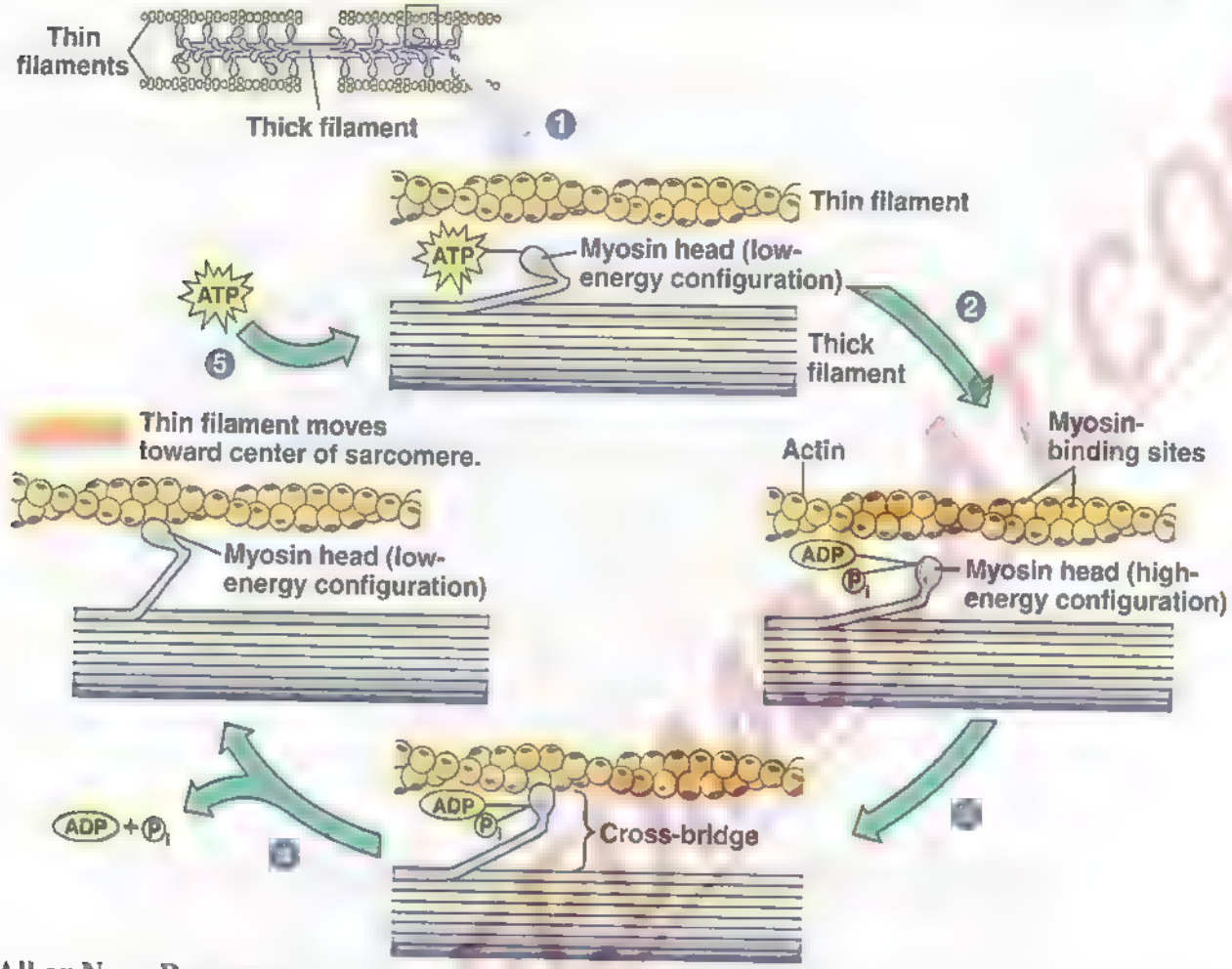
SLIDING FILAMENT MODEL AND ENERGY FOR MUSCLE CONTRACTION

H. Huxley and A. F. Huxley suggested this model of muscle contraction. Its salient features are given below:

- When muscle fiber contract, the **thin and thick filaments undergo shifting.**
- Thin filaments slide past the thick filaments.
- Actin and myosin filaments overlap to greater degree.
- The I-band reduces in length.
- Z-lines get closer.
- H-zone disappears.
- Length of A-band remains unchanged.
- Actin filaments come close to each other.

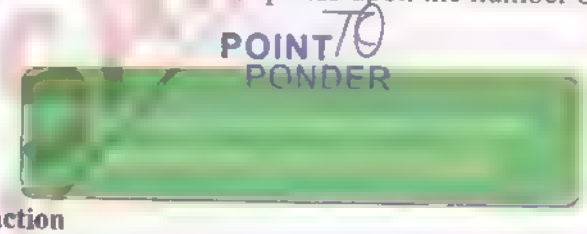
POINT TO PONDER

POINT TO PONDER



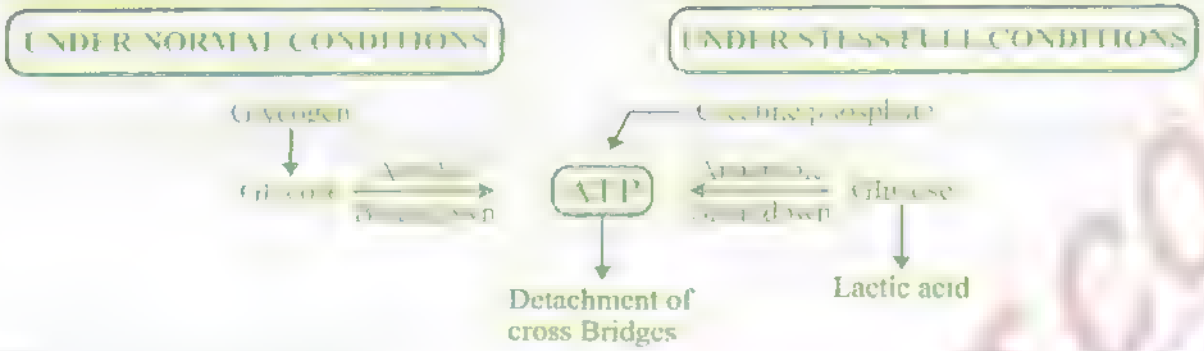
All or None Response

- All the fibrils of a muscle fiber will contract collectively in a particular contraction.
- However, the degree of contraction depends upon the number of participating fibers.



Energy for Muscle Contraction

- Energy for muscle contraction comes from ATP. Supply of ATP is maintained by the aerobic breakdown of glucose in muscle cell, which comes from stored glycogen in the cell.
- When more energy is required due to high metabolism, it is provided by another energy storing substance called creatine phosphate.
- Sometimes during oxygen deficiency or very high metabolic activity (such as prolonged or strenuous muscular activity), ATP requirement is met by anaerobic breakdown of glucose into lactic acid. Lactic acid accumulation causes muscle fatigue. At rest, 1/5 of lactic acid is broken aerobically and its energy is used to change the remaining 4/5 lactic acid into glucose.



Effect of Exercise on Muscles

- Increase in size of the muscle.
- Increase in its strength.
- More efficient and fatigue resistant.
- Capillaries surrounding muscle fibers and mitochondria in it increases
- Synthesize more myoglobin.

POINT TO PONDER

Disorder	Definition		
Muscle Fatigue	State of physiological inability to contract.	Relative deficit of ATP, Accumulation of lactic acid, Ionic imbalance	• Contracture formation • Drop in muscle pH • Muscle ache
Muscle Tetany	Characterized by muscle twitches and convulsions.	Low calcium in blood	• Increased excitability of neurons • Loss of sensations • Progresses to spasm of larynx, respiratory paralysis and ultimately death.
Muscle Cramp	Tetanic contraction of entire muscle.	Hypoglycemia, Dehydration, Electrolyte depletion, Irritability of spinal cord and nerves.	• Lasts for few second to hours, commonly at night or after exercise. • Muscles become taught or painful.
Tetanus	Acute infectious disease caused by anaerobic bacterium.	*Clostridium tetani*	• Persistent painful muscle spasm. • Begins with stiffness of jaws and neck muscles, progresses to lock jaw and spasm of trunk and limb muscles. • Fatal due to respiratory failure.

TOPIC-13 » COORDINATION & CONTROL

THIS TOPIC CONTENT

- Steps Involved in Nervous Coordination
- Sensory Receptors and Their Working
- Neurons (Structure and Types)
- Reflex Action and Reflex Arc
- Nerve Impulse
- Synapse
- Central Nervous System
- Peripheral Nervous System
- Nervous Disorder
- Hormones-The Chemical Messengers
- Endocrine System of Man (Hypothalamus)
- Pituitary Gland
- Thyroid Gland
- Parathyroid Gland
- Pancreas
- Adrenal Glands
- Gonads
- Hormonal Feedback Mechanism

STEPS INVOLVED IN NERVOUS COORDINATION

In almost all the animals' coordination is executed via neuronal and chemical (endocrine) systems.

Neuronal Coordination

- This type of co-ordination involves specialized cells or **neurons** linked together directly or indirectly via the central nervous system, to form network that connects the cell or organs which receive stimuli and those which carry out actions or responses.
- The neurons have the capacity to generate and conduct impulses which travel across the synapse.
- Three basic components of nervous system are:

(i) Receptors
(ii) Neurons
(iii) Effectors

SENSORY RECEPTORS AND THEIR WORKING

A cell or a neuron or a receptor organ which can detect changes in the external and internal environment of the animal is called a receptor.

Chemoreceptors	Smell, taste, blood CO_2, O_2, glucose, amino acids, fatty acids	Receptors in hypothalamus
Mechanoreceptors	Touch, pressure, hearing, equilibrium	Ear, skin, etc.
Photoreceptors	Light	Eyes (Rods and cone cells)
Thermoreceptors	Cold and warmth	Receptors in skin.
Nociceptors	Pain	e.g., in skin.

Working of Sensory Skin Receptors

- At least five different sensations are perceived by the skin, i.e., touch, pressure, heat, cold, and pain.
- There are at least three different types of sensory endings concerned with these sensations:

Receptor	Location	Structure	Sensation
Free Nerve Endings.	At the base of hair.	Free nerve endings.	Touch
Meissner's Corpuscles	In papillae which extend into ridges of the fingertips.	Specialized cellular encapsulated corpuscles, Spiral and twisted endings, each ending in a knob.	Touch
Pacinian Corpuscles	Deep in the body	Encapsulated neuron endings. Mostly located in the limbs.	Deep Pressure stimuli, vibration sensations.

Distribution of Receptors in the Skin

- Receptors are not evenly distributed throughout the skin rather are located at the sites of specific function.
- Their relative abundance also varies e.g.
  Pain receptors 27 X > Cold receptors.
  Cold receptors 10 X > heat receptors.

NEURONS (STRUCTURE AND TYPES)

- It is the basic structural and functional unit of nervous system.

POINT TO PONDER

- Neurons can generate and conduct nerve impulses which travel across synapses and pass from receptors to effectors, bringing about nervous coordination.
- Neuroglia cells mostly present in higher animals, playing important role in nutrition of neurons and their protection by myelin sheath. They constitute nearly half of the nervous system.
- Neurons once matured do not divide any further. However, they exhibit limited regenerative capabilities, only if neural cell body is intact.

Structure of Neuron

A typical neuron consists of:

(i) Cell body
(ii) Dendrites
(iii) Axons

POINT TO PONDER

Cell Body

- It is also called soma, is the **chief nutritional part** of the cell, and synthesizes materials necessary for growth and maintenance of neuron.
- It contains nucleus and other cellular organelles, like E.R, ribosomes, Golgi apparatus, mitochondria embedded in cytoplasm.
- **Nissl's granules** are group of ribosomes which are present in association with R.E.R.

- If it is intact, the neuron can regenerate its axonal and dendrital components.

Axons

- The processes **carrying impulses away from cell body** are called axons.
- Cellular organelles like mitochondria, microtubules and neurofibrils, R.E.R. and G.A are present throughout the axoplasm of the neuron.
- Most of the axons are surrounded by protective sheaths called **myelin sheath**, important for neuronal nutrition, protection and proper propagation of impulses.

Dendrites

- These are processes that **carry impulses towards the cell body**.
- These are usually thin fibres devoid of Schwann cells and thus non-myelinated.
- They unlike axon give a **spiny look**.

Myelin Sheath

- Neurons are surrounded by a layer, of fatty substance, called myelin sheath.
- It acts as insulator and gives white appearance.
- It is secreted by Schwann cells in peripheral nervous system.

Types of Neurons

There are three main types of neurons:

(i) Sensory Neurons

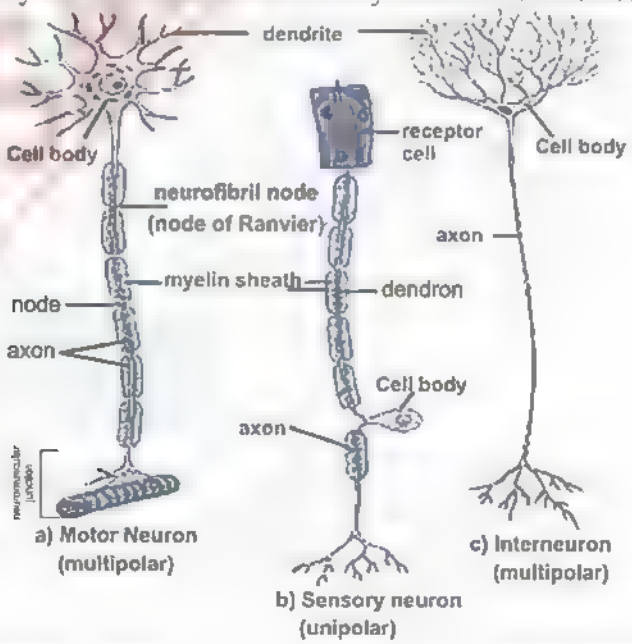
- Sensory neurons carry sensory information from receptors to associative neurons present in CNS.
- The dendrite endings of some sensory neurons also act as receptors.
- They usually have single long dendrite called Dendron. It is structurally and functionally similar to axon.

(ii) Associative Neurons

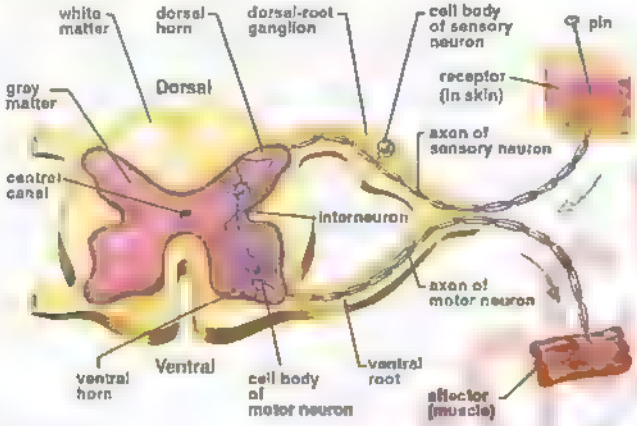
- Associative (intermediate/ relay / inter) neurons are present in CNS and connect sensory and motor neurons.
- They are involved in processing and interpretation of information coming from receptors.

(iii) Motor Neurons

- Motor neuronscarry the information from relay neurons to effectors.



- Reflex action is a type of involuntary action.
- Reflex arc is the pathway of the passage of impulse during a reflex action.
- It includes:
  Receptors → Sensory neuron → Intermediate neurons → Motor neurons → Effectors → Brings about the desired action.



Importance of Reflex Action

It helps an animal to save himself from danger e.g. when a person steps on a sharp object this message is immediately conveyed by the pain receptors to the spinal cord which results in contraction of the muscles of the leg and immediate withdrawal of the leg.

Definition

Nerve impulse is a wave of electrochemical changes, which travels along the length of neurons involving movement of ions across the membrane and chemical reactions.

Membrane Potential

- Electrical potential is the measure of the capacity to do electric work.
- The electrical potential that exists across a cell membrane is called membrane potential.

(i) Resting Membrane Potential

- Potential difference across the membrane when neuron is in **non-conducting state** is called resting membrane potential (RMP).
- Neuron in this state is in **polarized form.**
- A typical neuron at rest is **more positive electrically outside** than inside the cell membrane.
- Its value for a typical neuron is **-70 mV.**

(ii) Active Membrane Potential/ Action Potential

- Potential difference across the membrane when neuron is in conducting state is called active membrane potential (AMP).
- It is in form of nerve impulse. During this state, inner membrane surface becomes more positive than outside.
- Its value is **+50 mV.**

Ions Involved

- Na^+ and K^+ are most important in nerve cell and surrounding fluid.

- Na^+ is tenfold higher in concentration outside than inside the membrane surface.
- K^+ is twenty times more concentrated inside than outside.
- The large negative organic molecules/ions (such as proteins, organic acids etc.) are much more inside the membrane than outside. This makes the inside of neuron membrane more negative.

Channels Involved

- The cell membrane is virtually impermeable to all ions except K^+ so some K^+ leak out of the cell. The loss of these positive ions from neuron by diffusion accounts for more negative charges inside than outside.
- All the neurons have very active sodium and potassium pumps located in their cell membranes. Driven by the splitting of ATP, these pumps transport 3 Na^+ out and 2 K^+ into the cell, against their concentration gradient.
- Cell membrane has sodium and potassium gates which when open allow movement of ions along the concentration gradient.

Initiation of Nerve Impulse

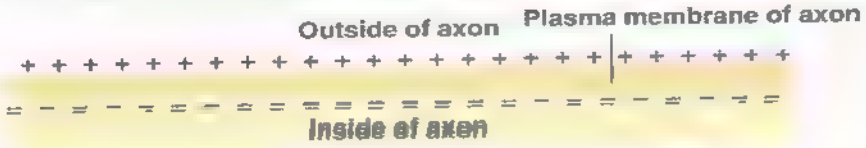
- Under normal conditions, a nerve impulse is initiated by an appropriate stimulus (threshold stimulus) applied at one end of neuron.
- Minimum intensity of stimulus that is required to initiate a nerve impulse is called **threshold stimulus**.
- It results in a remarkable localized change in the resting membrane potential. It disappears for a brief instant and is replaced by action potential. This change is so brief (for a millisecond) that only a portion of neuron is in active state.

Conduction of Nerve Impulse (RMP → AMP)

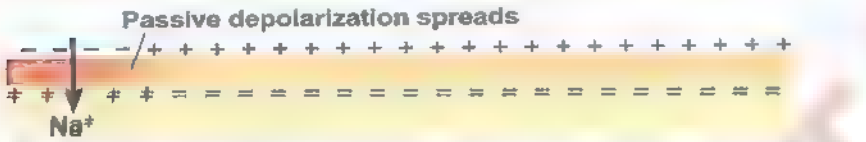
- The passage of nerve impulse is associated with increase in permeability of Na^+ moving inwards upsetting the potential momentarily, making the inside more positive than outside.
- This increased permeability is due to opening of sodium gates. When these gates open, Na^+ rush into the neuron by diffusion. Some K^+ moves out.
- The inner side of the cell membrane has excess of positive ions and outer surface becomes more negative.
- During active membrane potential, the neuron conducts the impulse in the form of nerve impulse.
- These changes occur along the length of neuron till the impulse reaches synapse.
- Soon after the passage of impulse, the resting membrane potential is restored by the movement of a small number of ions especially K^+ moving out. This neuron is now ready to conduct another impulse.

Repolarization of Neuron (AMP → RMP)

- It is the restoration of resting membrane potential, after the wave of depolarization has passed.
- Results from closure of Na^+ gates and opening of K^+ gates, without flux of K^+ ions, causing repolarization
- Na^+/ K^+ pump restore the original ionic gradient and thus the resting potential.
- The whole process of depolarization and repolarization takes about 2- 3 millisecond

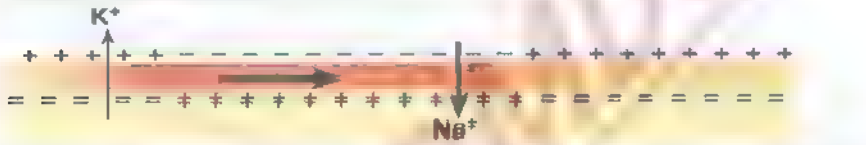


1 At the start, the membrane is completely polarized.



2 When an action potential is initiated, a region of the membrane depolarizes. As a result, the adjacent regions become depolarized.

3 When the adjacent region is depolarized to its threshold, an action potential starts there.



4 Repolarization occurs due to the outward flow of K^+ ions. The depolarization spreads forward, triggering an action potential.

5 Depolarization spreads forward, repeating the process.

Speed of Nerve Impulse

- Normal speed in humans is 100 m/s but can reach up to 120 m/s.
- The nerve impulse is conducted from node to node in jumping manner. This kind of jumping nerve impulse is called **saltatory impulse**.

- Cytoplasmic gaps between consecutive neurons are called **synapse**.
- A single neuron may form synapses with many incoming fibres of different neurons.
- A single nerve impulse does not necessarily get across the synapse. It may take two or three impulses arriving in rapid succession or perhaps simultaneously from two or more fibers to start an impulse in the next neuron.

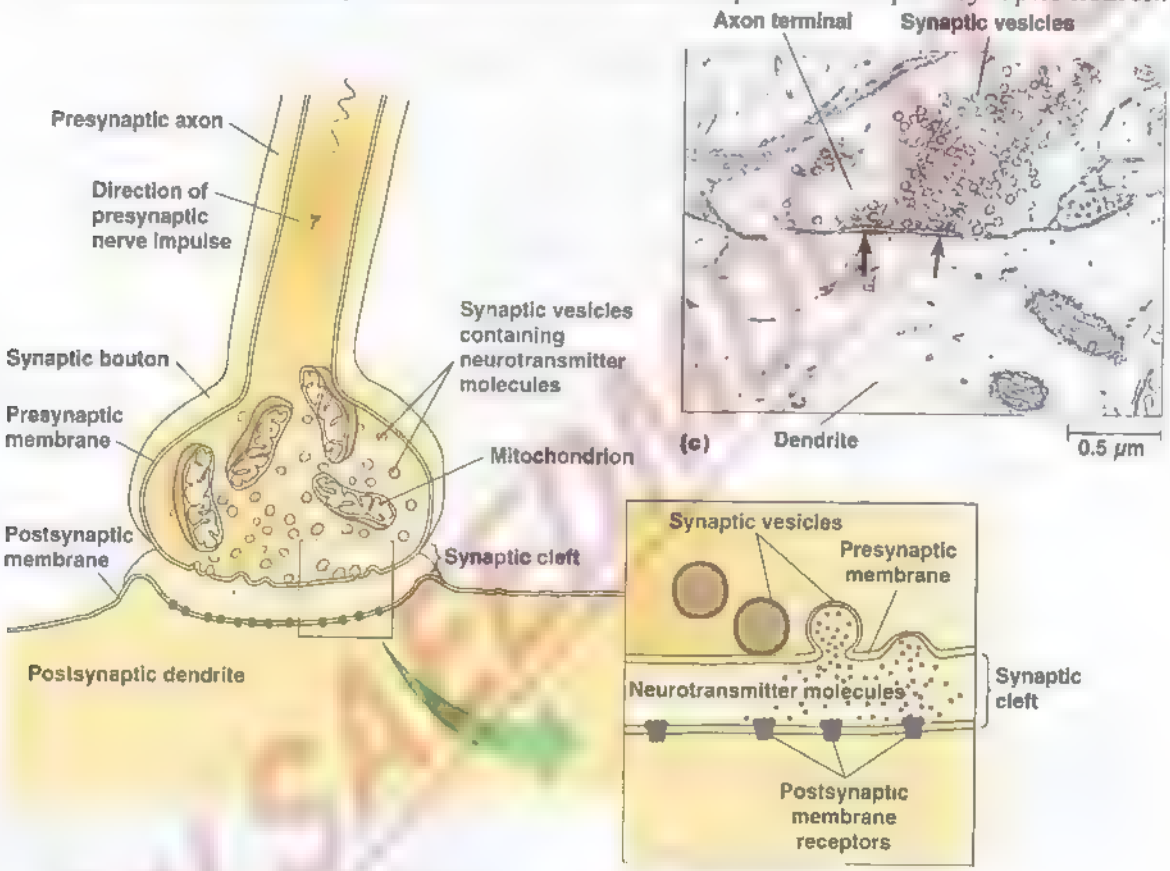
Neurotransmitters

- The action potential cannot jump from one neuron to the next in line; rather the message is transmitted across synapse in the form of chemical messenger called neurotransmitters.
- Neurotransmitters are chemicals, which are released at the axon ending of the neurons at synapse.

- **Acetylcholine** is neurotransmitter for synapse outside CNS while adrenalin, nor-epinephrine, serotonin and dopamine in CNS.

Mechanism of Synaptic Transmission

- When an impulse reaches a synaptic knob, synaptic vesicles within it fuse with the pre-synaptic membrane.
- These vesicles cause release of neurotransmitter molecules into the **synaptic cleft**.
- Neurotransmitter molecules bind to the receptors on post-synaptic membrane, causing changes in its permeability to certain ions.
- Change in permeability causes initiation of nerve impulse in the post-synaptic neuron.



There are two types of synapses;

(i) Electrical synapses

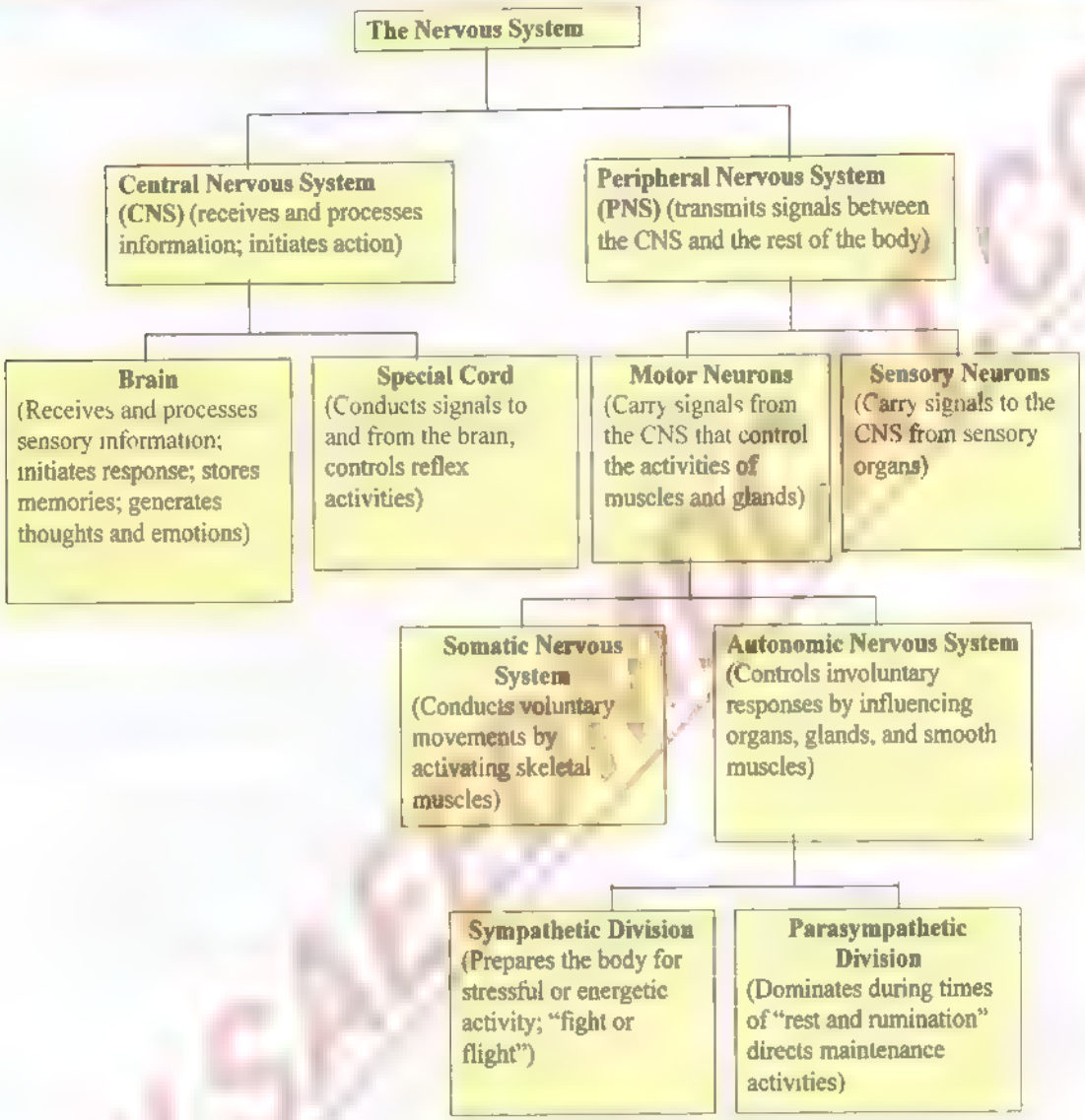
(ii) Chemical synapses

Electrical synapses

- In electrical impulse, which are specialized for rapid signal transmission, the cells are separated by a gap, the synaptic cleft, of only 0.2nm, so that an action potential arriving at the pre synaptic side of cleft, can sufficiently depolarize the post synaptic membrane to directly trigger its action potential.

Chemical synapses

- The majority of synapses are chemical synapse where synaptic cleft has gap of more than 20nm.
- Through these synapses, information of impulse from one neuron is transmitted to another by means of chemical messengers, the neurotransmitters.



- The central nervous system consists of brain and spinal cord
- Both brain and spinal cord are hollow. The spinal cord has central canal and brain has many cavities (ventricles).
- Both are protected in three ways.

(i) Cranium, which is part of skull, protects the brain and neural arches of vertebrae of vertebral column protect the spinal cord.

(ii) The brain and spinal cord are also protected by three layers of meninges.

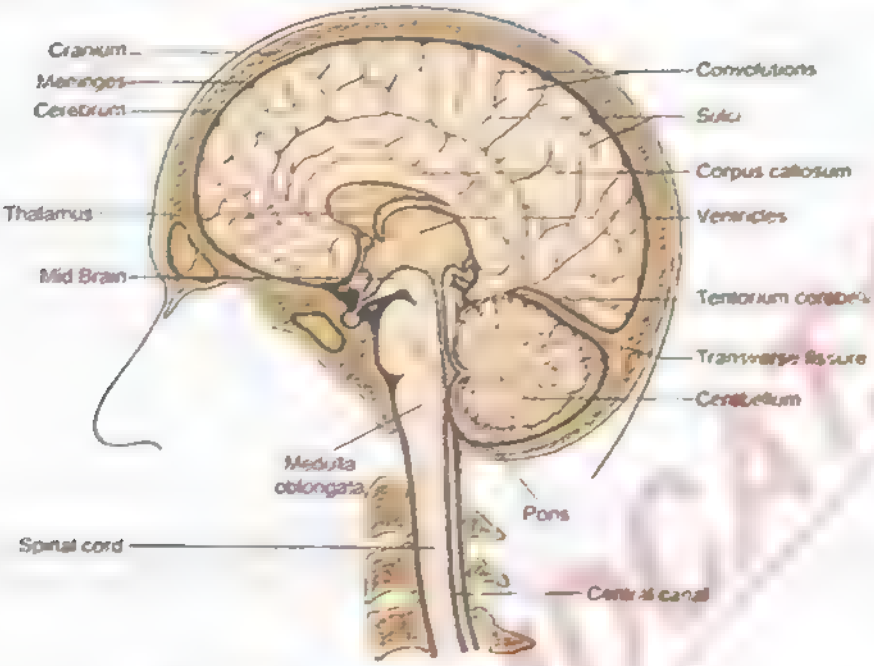
(iii) CSF bathes the neurons of brain and spinal cord and cushions against the bumps and jolts. Its composition is similar to blood plasma. It is found in cavities of brain and spinal cord and between meninges.

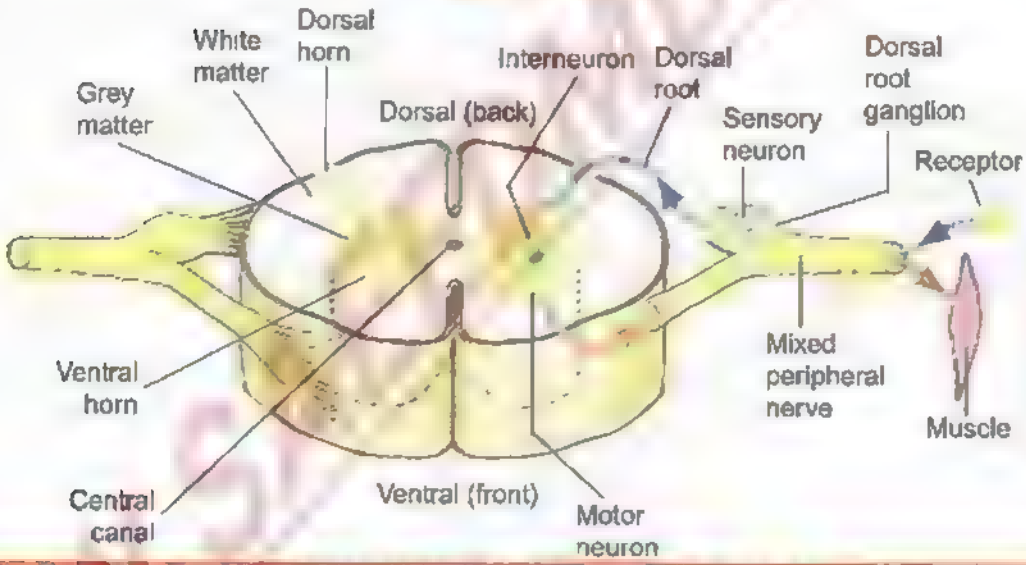
POINT TO PONDER

Write names of 3 layers of

Parts	Sub-Parts	Anatomical Features	Physiological Features
Forebrain	Thalamus	Relay centre	Relay between sensory input from eyes, ears, skin etc to limbic system & cerebrum
	Limbic system (Arc between thalamus & cerebrum)	Hypothalamus	• Hormone production • Major coordinating center • Controls body temperature, hunger, menstrual cycle, water balance, sleep-wake cycle.
		Amygdala (cluster of neurons)	• Sensation of pleasure, punishment, sexual arousal • Feeling of fear & rage
		Hippocampus	• Long-term memory • Learning
	Cerebrum	• Largest part • Two halves (cerebral hemispheres) • Corpus callosum (band of axons) • Outer cerebral cortex forming convolutions	• Receives sensory information • Processes it • Stores in form of memory • Direct voluntary movement • Responsible for thinking, intelligence, reasoning, judgment. • Sensory area, speech area, motor area, association areas • Right cerebral hemisphere controls left side of body and vice versa.
Midbrain (reduced in human)	Reticular formation		• Relay center connecting hindbrain with forebrain • Screening input information • Contains auditory relay station,
Hindbrain	Pons		• Influence transition between sleep & wakefulness • Controls rate & pattern of breathing
	Medulla		Controls autonomic functions e.g. • Breathing • Heart rate • Blood pressure • Swallowing
	Cerebellum (best developed in birds)	2nd largest part 2 cerebellar hemispheres connected by vermis.	• Coordinates voluntary movements • Guides smooth & accurate motions • Maintains body position • Learning & memory storage for behaviours.
Spinal Cord		• Oval shaped hollow cylinder • Runs throughout vertebral column • Inner butterfly shaped gray matter • Central canal • Outer white matter	• Centre for many reflexes • Pathway for conduction of impulses to and from different parts of body and brain.

- Gray matter consists of cell bodies and non-myelinated nerve fibers or tracts.
- White matter is made up of myelinated nerve fibers or tracts.





- It consists of sensory neurons and motor neurons, which may form ganglia and the nerves.
- **Ganglia** are concentrations of cell bodies of neurons. Ganglia often interconnect with other ganglia to form a complex system called plexus.
- The **nerves** are the bundles of axons or dendrites, bounded by connective tissue.

POINT TO PONDER

Can you explain the role of vagus nerve?

Classification of Nerves

Functional Classification

- They may be sensory, motor or mixed nerves depending upon the direction of impulse they conduct.
- Mixed nerves contain both sensory and motor neurons.

Regional Classification

- Nerves which arise or lead to brain are called cerebral or cranial nerves. There are 12 pairs of cranial nerves in humans. Some of these are sensory, some motor and some are mixed. All these supply to only head except for vagus nerve which extends even up to abdomen.
- Nerves that arise or lead to spinal cord are called spinal nerves. There are 31 pairs of spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal) and all are mixed nerves.

Classification of PNS

- Motor neurons form **somatic nervous system**, which controls voluntary movements, which are under conscious control of the body, involving skeletal muscles.
- The motor neurons from **autonomic nervous system** which control involuntary responses are divided into the sympathetic and parasympathetic nervous system.

Autonomic Nervous System

- It controls involuntary responses by influencing organs, glands and smooth muscles.
- It is classified into sympathetic and parasympathetic divisions.

Features		
Origin	Middle portion of spinal cord	Bottom portion of spinal cord + cranial nerves (vagus nerves)
	Thoracic region	Lumbar region
Position of ganglia	Near spinal cord	Near effectors
Length of pre-ganglionic fibers	Short	Long
Length of post-ganglionic fibers	Long	Short
Functions	Works in emergency, fear and fight situations	Promotes relaxed state
Actions	• Accelerates heartbeat • Dilates pupils • Inhibits digestion of food • Rise in blood pressure	• Retards heartbeat • Constriction of pupils • Promotes digestion of food • Lowering of blood pressure

POINT TO PONDER

divisions of ANS?

POINT TO PONDER

NERVOUS DISORDERS

Feature	Parkinson's Disease	Epilepsy	Alzheimer's Disease
Definition	It is a nervous disorder, characterized by involuntary tremors, diminished motor power and rigidity.	It is a convulsive disorder of nerves characterized by abrupt transient symptoms of motor, sensory, psychic or autonomic nature, frequently associated with changes in consciousness.	It is characterized by decline in brain function.
Onset	Late age disease (50's or 60's)& Progressive	Before 30 years of age Organic disease after 30 years	Late age disease & progressive
Cause	Cell death in brain area that produces dopamine that may be due to head trauma	No known cause. Emotional disturbance, alcohol etc. are aggravating factors	Genetic predisposition, High levels of aluminium
Treatment	L-dopa, Use of GDNF	EEG for diagnosis, Anti-convulsive drugs for therapy	Non-curable

HORMONES-THE CHEMICAL MESSENGERS

- Hormones are organic compounds of **varying structural complexity**.
- They are poured directly and are transported to the blood to respective target cells/tissues
- They **do not initiate new biochemical reactions** but produce their effects by regulating enzymatic and other chemical reactions already present.
- They may either stimulate or inhibit a function.
- Hormones may also control some long-term changes, such as rate of growth, rate of metabolic activity and sexual maturity.

Types of Hormones

- Chemically hormones may be of following four types:

Category	Gland	Hormone
Protein	Islets of Langerhans	Insulin, Glucagon
Polypeptides	Posterior pituitary	ADH, Oxytocin
Amino Acids and Derivatives	Thyroid, Adrenal Medulla	T3, T4, Epinephrine, Nor-epinephrine
Steroid	Gonads, Adrenal Cortex	Estrogen, Testosterone, Cortisone.

ENDOCRINE SYSTEM OF MAN (HUMANS)

Glands

- These are the organs that are specialized for secretions. Glandular cells are secretory or neurosecretory cells that have abundant Golgi bodies.
- Hormones released from neurosecretory cells are called as neurosecretions e.g. ADH is neuropeptide.
- Glands can be divided into two main categories i.e. exocrine and endocrine glands.
- Endocrine system of human consists of about 20 endocrine glands.

Feature	Exocrine Glands	
Another Name	Ducted glands	Ductless glands
Secretions	Enzymes, mucus etc.	Hormones
Transportation	Through ducts	Through blood
Examples	Sweat glands, Salivary glands	Adrenal glands, Pituitary gland

Hypothalamus

- It is a part of forebrain. It has neurosecretory cells which produce and secrete a variety of hormones.
- It is here that many of the sensory stimuli of nervous system are converted into hormonal responses.
- It is believed that oxytocin and ADH are produced in hypothalamus and travel down the nerves to the posterior lobe of pituitary to be stored in nerve endings. They are released from posterior pituitary after receiving nerve impulses from the hypothalamus.
- Another cluster of neurons in hypothalamus produce and secrete a battery of releasing and inhibiting hormones, which are carried by the blood to the anterior pituitary. These regulate the secretion of many tropic hormones, growth hormones and prolactin manufactured by the anterior pituitary cells

- In man, the pituitary gland or hypophysis cerebri is an ovoid structure about 0.5gm in the adult and is connected to brain through a short stalk (the infundibulum).
- It has three lobes viz, anterior, median and posterior.
- The anterior lobe is often referred to as the **master gland**, because in addition to producing primary hormones it produces the tropic hormones which control the secretion of hormones in many of the other endocrine glands.

Anterior Lobe

(i) Somatotrophin Hormone (STH)

- It is also called as growth hormone.
- Hypothalamus → SRF → Anterior Pituitary → STH → Growth
- Somatotrophin releasing factor (SRF) is secreted from hypothalamus throughout life.
- When growth has mostly ceased after adolescence, the hormone continues to promote protein synthesis throughout the body.
- If produced in excess during early life, leads to **gigantism** or if later in life causes the abnormal development of hands, feet, jaws etc. (known as **acromegaly**).
- If there is under secretion, **dwarfism** results, as well as other symptoms associated with lack of thyroid and adrenal hormone.

(ii) **Thyroid Stimulating Hormone (TSH)**

- Thyroxine in Blood → Hypothalamus → TRF → Anterior Pituitary → TSH → Thyroid Gland → Thyroxine
- Release of thyrotrophin releasing factor from the hypothalamus is controlled by the levels of thyroxine in the blood.
- In the presence of low levels of thyroxine, there is increasing production of TSH and vice versa.
- It is secreted throughout life but particularly reaches high levels during the periods of rapid growth and development.
- It acts directly on the cells of thyroid gland, increasing both their numbers and secretory activity.

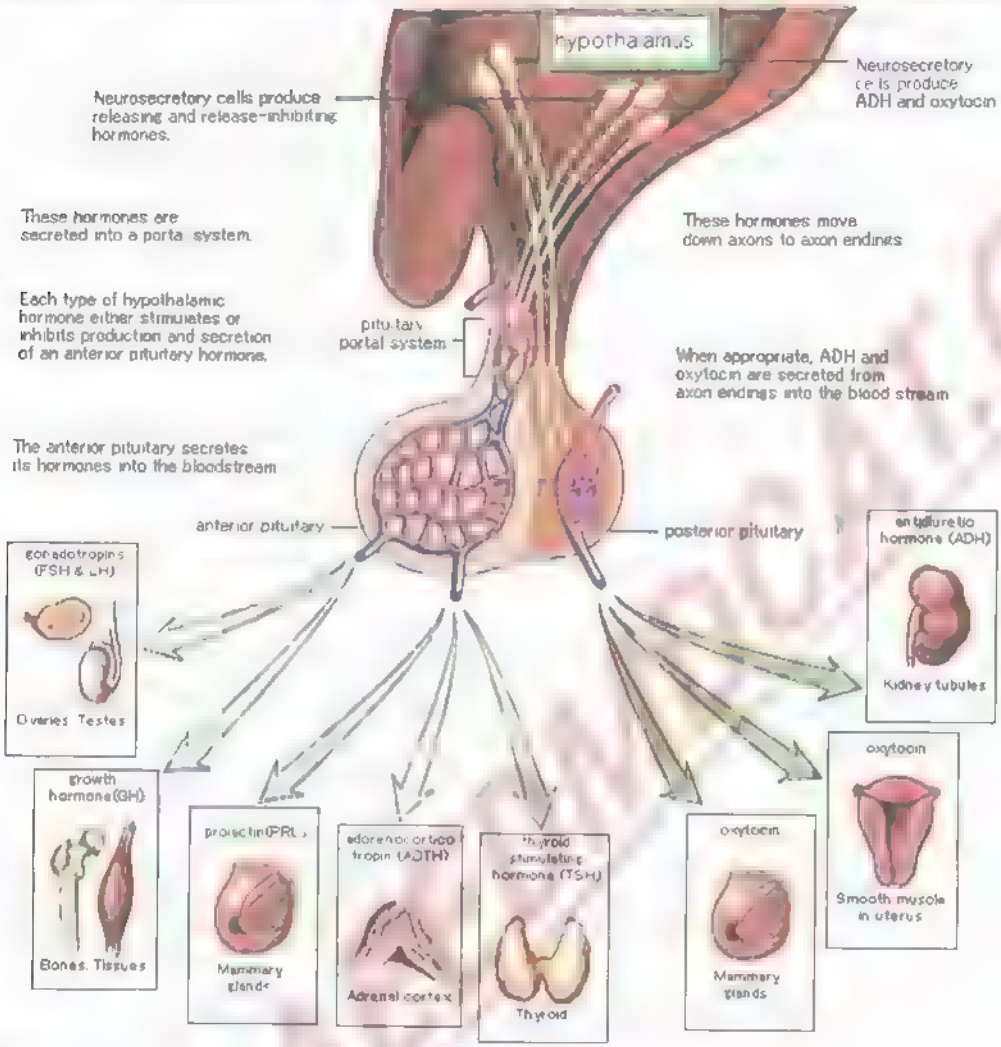
(iii) **Adrenocorticotrophic Hormone (ACTH)**

- Steroid in Blood → Hypothalamus → CRF → Anterior Pituitary → ACTH → Adrenal Cortex → Corticosteroid
- Release of corticotrophin releasing factor from the hypothalamus is controlled by steroid levels in the blood and by direct nervous stimulation of the hypothalamus as a result of stress e.g. cold, heat, pain, fright, infections.
- Excess and deficiency results in disturbance of normal adrenal functions

(iv) **Gonadotrophic Hormone (GH)**

- These are follicle stimulating hormone (FSH), luteinizing hormone (LH, also called ICSH in male) and prolactin (sometimes inappropriately called luteotrophic hormone, LTH).
- FSH and LH ICSH share a common hypothalamic releasing factor.
- Prolactin is continuously produced from the pituitary and is inhibited by prolactin inhibiting factor (PIH) from the hypothalamus.
- Prolactin stimulates milk production and acts with LH.
- FSH in females stimulates follicle development and secretion of estrogen from the ovaries; in males it stimulates development of the germinal epithelium of testes and sperm production.
- LH works with FSH to stimulate estrogen secretion and rupture of mature follicles to release egg or ovum.
- It also causes the lutenization of mature follicles and acts synergistically with prolactin to maintain corpus luteum (and hence the progesterone it secretes).

- ICSH in the male stimulates the interstitial cells of the testes to secrete testosterone.



Median Lobe

- Median lobe secretes MSH.
- Its inhibition of secretion is controlled by hypothalamus.
- External light governs its secretion.
- More secretion in pregnancy stimulates melanocytes in skin to produce brown pigment, melanin, which darkens the skin.
- Excess MSH is secreted in Addison's disease. One of the symptoms of which is darkening of skin.

POINT TO PONDER

Posterior Lobe

1. **Antidiuretic Hormone (ADH)/ Vasopressin**

- Its secretion is caused by decrease in blood pressure, blood volume and osmotic pressure of the blood which is detected by osmoreceptors in hypothalamus.
- External sensory stimuli also influence hypothalamic neurosecretory cells.
- Increased levels cause increased water reabsorption in distal parts of nephron.
- A lack of this hormone produces **diabetes insipidus**, characterized by production of large quantities of dilute urine and great thirst.

2. Oxytocin

- Its release is stimulated by distension of cervix, decrease in progesterone level in blood and neural stimuli during parturition and suckling.
- Primary action is on smooth muscles, particularly in the uterus during child birth and also causes milk ejection from mammary glands.

Introduction

- Thyroid gland is located below the larynx (voice box).
- These are two in number.

Hormones

- Thyroxin (Tetra-iodothyronine/ T4)
- Tri-iodothyronine (T3)
- Calcitonin

Control

- T3 and T4
  Negative physiological control by anterior pituitary (master gland) via tropic hormone TSH (Thyroid stimulating hormone)
- Calcitonin
  Circulating calcium levels in blood

Functions

T3 and T4

- Both act essentially in the same way.
- They act on basal metabolic rate by stimulating the breakdown of glucose and release of heat and generation of ATP.
- They also act in conjunction with somatotropin in bringing about growth.
- They act directly on brain cells causing them to differentiate.

Calcitonin

It regulates blood calcium level. High Ca^{+2} ion concentrations in the blood causes stimulation of the synthesis and release of calcitonin.

Abnormalities of T3 and T4

Overproduction

- Excess thyroxine produces a condition called **Graves' disease** which is characterized by **exophthalmic goiter** and increase in the basal metabolic rate.
- This can lead to cardiac failure if prolonged.
- It is caused by production of an abnormal body protein which continuously stimulates thyroid to excessive secretion.

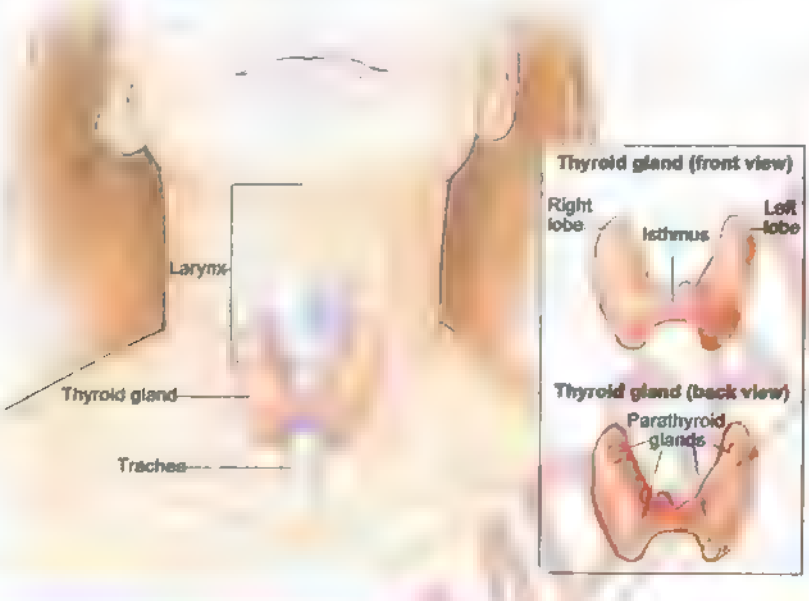
Under-secretion

- If congenitally deficient, the lack of thyroxin causes **cretinism**, where individuals fail to develop normally. They are small, have coarse scanty hair, thick yellowish skin and are mentally retarded. They also fail to develop sexually.
- Deficiency later in life, perhaps due to iodine deficiency, produces swelling of neck (goiter) and may lead to deposition of excess fat as a result of which weight is increased. This condition is known as **myxedema**. It is characterized by puffiness of hand and skin. All body and mental processes are retarded.

POINT TO PONDER

Abnormalities of Calcitonin

- Excess or deficiency leads to disturbance of calcium metabolism with its associated effects on nerve, skeleton, muscle, blood etc.



Introduction

- In man, the glands are found embedded in the posterior part of the lateral lobes of the thyroid.
- These are four in number.

Hormone

- These produce a hormone called parathormone.

Control

- Low levels of Ca^{+2} ions stimulate the parathyroid directly to increase the parathormone production.
- High levels of Ca^{+2} ions suppress its release.

Abnormalities

- Under-activity causes a drop in blood Ca^{+2} ions which in turn leads to muscular tetany.
- Over-activity would lead to a progressive demineralization of the bones similar to rickets, as well as to the formation of massive kidney stones.

Introduction

- Pancreas is a dual gland that acts **both as exocrine and endocrine glands.**
- Endocrine portion of pancreas contains Islets of Langerhans.

Hormones

- The Islets contain large number of β-cells associated with insulin production.
- The smaller number of α-cells secretes glucagon.

Control

- This is under control of the pituitary trophic hormones, STH and ACTH and also responds directly to the level of blood glucose.

Metabolic Functions of Insulin

- In general, insulin depresses blood glucose levels, in a variety of ways which include:

(i) Increasing glycogen synthesis
(ii) Increasing cell utilization of glucose
(iii) Stimulates conversion of glucose into proteins and lipids, which in turn reduce glucose levels
(iv) Inhibit the hydrolysis of glycogen in the liver and muscles

Metabolic Functions of Glucagon

- Glucagon is essentially **antagonistic to insulin** and causes an increase in blood glucose levels. It does this mainly by:

(i) Promoting breakdown of glycogen to glucose in the liver and muscles
(ii) Increasing the rate of breakdown of fats

Abnormalities of Insulin

Under-secretion

POINT TO PONDER

How is type I diabetes mellitus with type II diabetes?

- Failure to produce insulin leads to a condition called **diabetes mellitus**. The symptoms include:

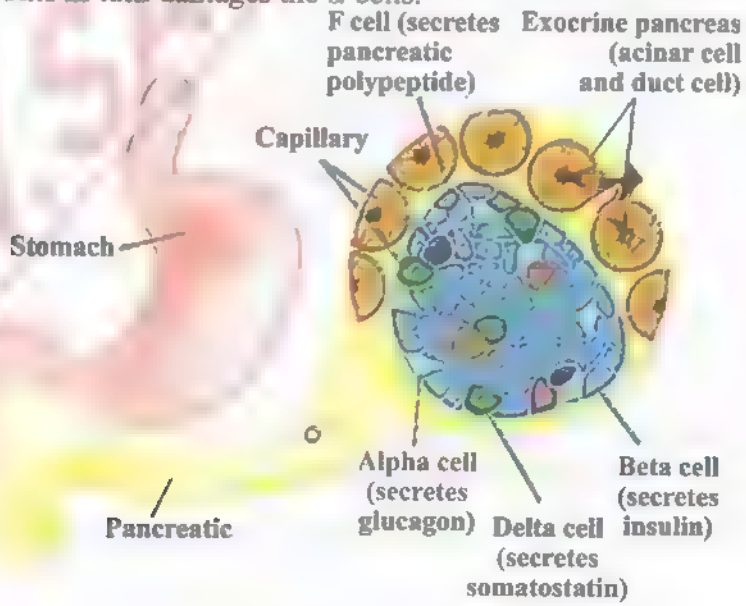
(i) High level of blood sugar
(ii) Sugar in the urine
(iii) A disturbance of the body's osmotic equilibrium
(iv) Derangement of the nervous system
(v) Toxic metabolites from fat (which need 'glucose energy' for their oxidation) also accumulate and are only lost from the kidney with valuable metal cations.
(vi) The body becomes dehydrated.

Overproduction

- If excess insulin is produced, the utilization of sugar is too great and its level falls in the blood (hypoglycemia) which upsets nerve and muscle functioning.

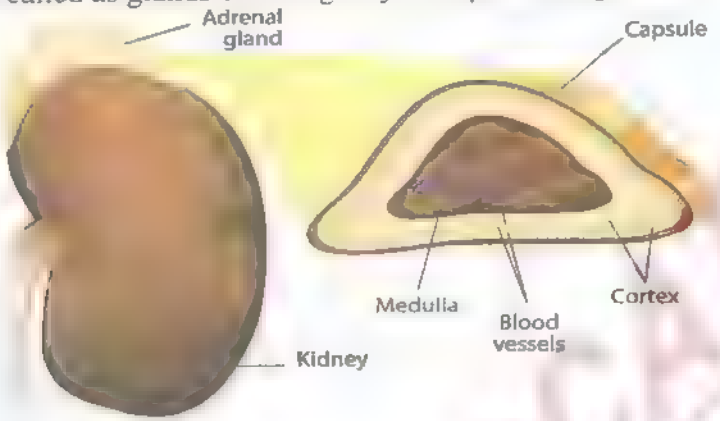
Abnormalities of Glucagon

- Glucagon abnormalities seem rare as endocrine disorders.
- Tumors on the β-cells will cause excess glucagon secretions and consequently high blood glucose levels. This in turn damages the α-cells.



Introduction

- A pair of adrenal gland is present, one on top of each kidney.
- These are also called as glands of emergency or supra-renal glands.



Adrenal Medulla

- Inner portion of adrenal gland is called adrenal medulla.

Hormones

- The medulla produces the hormones adrenaline (epinephrine) and noradrenalin (nor-epinephrine).

Control

- Both adrenalin and nor-adrenalin are secreted in stress situations.
- They are influenced by sympathetic nervous system.

Functions

- Essentially adrenaline dilates blood vessels in certain parts of the body such as the skeletal muscles and increases the heart's output.
- Noradrenaline constricts blood vessels but again only in certain areas such as the gut.
- Effects of the two hormones are synergistic in raising blood pressure.
- Adrenaline and noradrenaline promote the release of glucose from liver glycogen and reinforce the effects of the sympathetic system.

Abnormalities

- Rarely found, but in excess, these hormones lead to abnormally high blood pressure.
- In rats whose adrenal medulla has been removed surgically, the ability to withstand any stress situation – such as cold – is markedly diminished.

Adrenal Cortex

- Outer portion of adrenal gland is called adrenal cortex.

Hormones

- The adrenal cortex secretes corticosteroids such as cortisol, corticosterone, aldosterone and androgenic hormones.
- Cortisol is the glucocorticoid.
- Corticosterone is both a glucocorticoid and a mineralocorticoid.
- Aldosterone is the principal mineralo-corticoid.

Control

- Hormones of adrenal cortex are secreted under influence of ACTH from adrenal cortex.

Functions

- The adrenal cortex is active at all times but especially so following shock or stress situation or infections.

- Cortisol brings about an increase in blood glucose level mainly by its production from protein and antagonizing the action of insulin.
- Corticosterone increases blood glucose levels and regulate mineral ion balance.
- Aldosterone conserves the level of Na^+ in the body by preventing their loss from the kidney tubules.

Abnormalities

Under-secretion of Corticosteroids

- The destruction of the adrenal cortex, such as occurs in **Addison's disease,** will lead to general metabolic disturbance, in particular weakness of muscle action and loss of salts.
- Stress situations, such as cold, which would normally be overcome, lead to collapse and death.

Overproduction of Corticosteroids

- The reverse of this is found in Cushing's disease where too much cortical hormone is produced. Symptoms are an excessive protein breakdown resulting muscular and bone weakness. The high blood sugar disturbs the metabolism as in diabetes.

Overproduction of Androgens

- Androgens cause development of the secondary male characteristics.
- Very small amounts of androgens are secreted in both male and female by adrenal glands.
- A tumor on the inner part of the adrenal cortex in a female can cause excess androgens to be produced and thus the development of certain male characteristics. Such cases are very rare.

POINT TO PONDER

affect muscle

Ovaries

Hormones

Ovaries are involved in production and secretion of female sex hormones mainly estrogen and progesterone.

Estrogen

Production and Control

- Oestrogens are secreted by ripening follicles whose development has been initiated by FSH from the pituitary.
- In many species produced by interstitial cells of the ovary.

Functions

- Bring about the development of the secondary sexual characters in the female.
- Cause thickening of uterine wall.
- At a point during the estrous or menstrual cycle, exert a positive feedback which results in a sharp rise in LH output by the pituitary.
- They also aid in healing and repair of uterine wall after menstruation.
- Under the influence of estrogen, some of the cells of uterine wall become glandular and start secreting proteinaceous secretions which are taken up by the embryo during its early stages of development.

Abnormalities

- Deficiency of the sex hormones, for one reason or another, leads in the young of failure to mature sexually and sterility in the adult.

Progesterone

Production and Control

- Produced by the ruptured follicle in response to LH from the pituitary

Functions

- It inhibits further FSH secretion from the pituitary, thus preventing any more follicles from ripening.
- It also affects uterus, causing further thickening and vascularization of its wall and other areas of the female body, preparing it for maintaining the state of pregnancy.
- It suppresses ovulation that is why it is a major constituent of birth control pill.

Testes

Hormones

- The testes consist of many coiled seminiferous tubules where the spermatozoa develop.
- Between the tubules, regions of interstitial cells produce gonadal hormones called testosterone and 17 β-hydroxytestosterone.
- After the initiation of development, the sex organs in the foetus produce them and their level rises fairly consistently until puberty.
- After puberty the supply of LH (ICSH), and therefore the level of testosterone, remains constant.

Functions

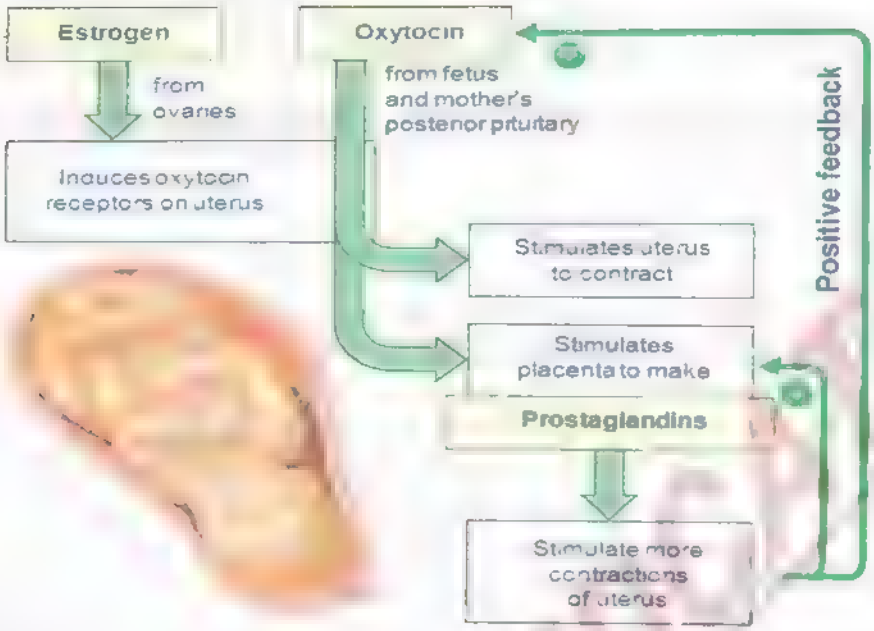
- In the foetus, it initiates the development of the sex organs.
- At puberty, it brings about development of the male secondary characteristics and promotes the sex drive.
- The castrated male fails to develop secondary sexual characteristics and his body tends more towards the form of the immature female.

HORMONAL FEEDBACK MECHANISM

- It is a type of interaction in which a controlling mechanism is itself controlled by the products of reactions it is controlling.
- After receiving the signal, a change occurs to correct the deviation by depressing it with negative feedback or enhancing it with positive feedback.

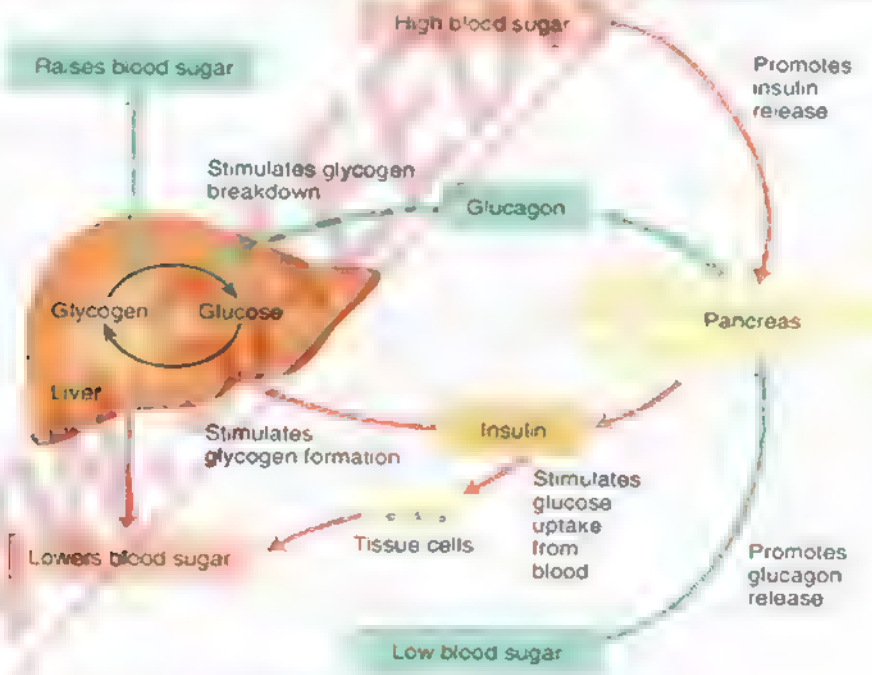
Positive feedback

- These responses are not homeostatic and are rare in healthy individuals.
- In positive feedback, an end product speeds up its production.
- An example of positive feedback is childbirth.



Negative feedback

- In this system, an endocrine gland is sensitive either to the concentration of a substance it regulates or to the concentration of a product from a process it controls
- For example, regulation of blood glucose in the blood by pancreatic endocrine cells.



POINT TO PONDER

and negative feedback mechanism?

TOPIC-14 REPRODUCTION

- Male Reproductive System
- Female Reproductive System
- Menstrual Cycle
- Sexually Transmitted Diseases

Gonads

- Male gonads consist of a **pair of testes**, which lie outside the body, in sac-like scrotum.
- Each testis consists of a highly complex duct system called seminiferous tubules, in which repeated division by the cells of the germinal epithelium produces spermatogonia.
- Seminiferous tubules also contain **sertoli cells/ nurse cells,** which provide liquid medium, protection and nourishment to cells while they are in the tubules. These cells also secrete inhibin hormone which serves to control the spermatogenesis at normal rate.
- **Interstitial cells/ leydig cells** are present between the seminiferous tubules and secrete testosterone essential for production of sperms and development of male secondary sexual characteristics during puberty.
- Both germinal epithelial cells and sertoli cells are under the control of FSH while interstitial cells are under the control of ICSH.

External Genitilia

- **Penis** is copulatory organ and external genitalia, which is used to transfer sperm into female reproductive tract.

Duct System

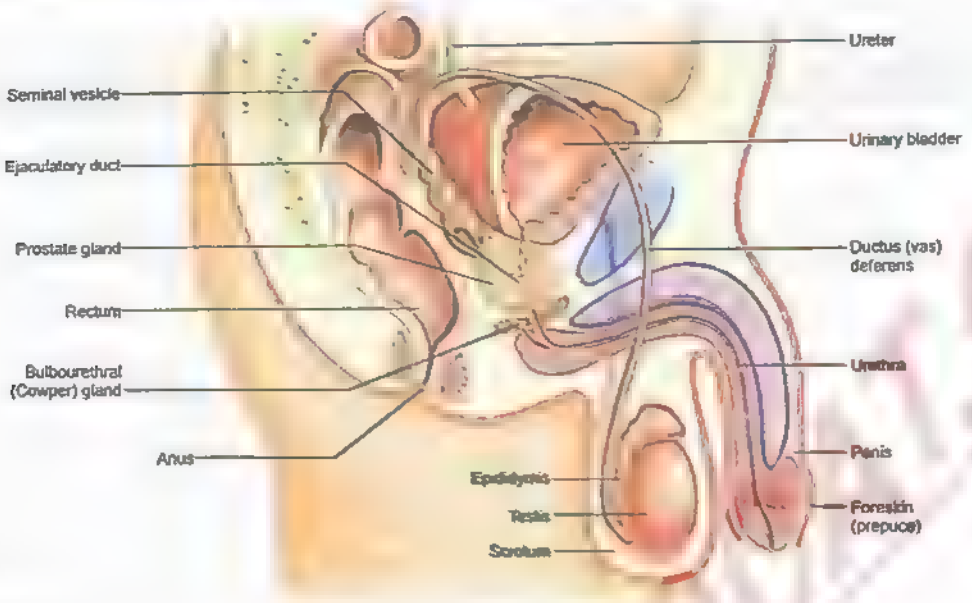
- **Seminiferous tubules** are the sites for spermatogenesis.
- **Epididymis** is the proximal highly convoluted portion of vas deferens where maturation of sperms is completed; they become motile and are stored.
- **Vas deferens** (sperm duct) is the main duct of male reproductive tract.
- Part of vas deferens that receives secretions from seminal vesicles is called **ejaculatory duct**.
- Urethra in male is also called as urinogenital duct because it transfers both urine and semen outside the body.

Glands

- Testes are endocrine glands which are paired and produce male sex hormones, most important of which is testosterone.
- Seminal vesicles, prostate and bulbourethral/cowper's glands are exocrine glands

POINT TO PONDER

esicles and Prostate gland?



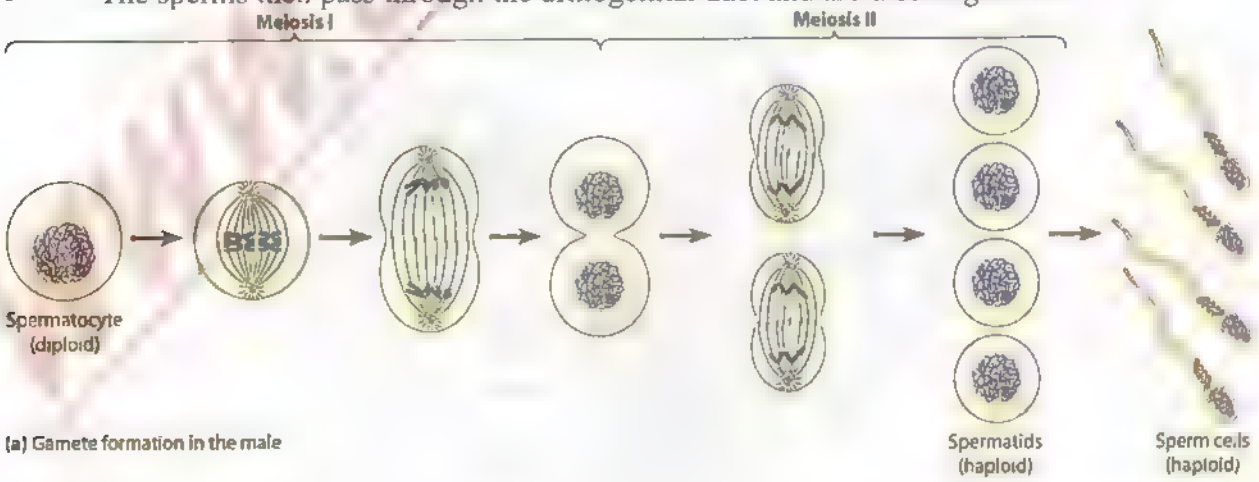
Gametogenesis

- Gametogenesis is defined as 'the process whereby a haploid cell or gamete is formed from a diploid cell through meiosis and cell differentiation.'

Spermatogenesis

- Gametogenesis in the male is known as spermatogenesis and produces spermatozoa/sperm.
- Spermatogonia are present in the seminiferous tubules can increase in size and differentiate into primary spermatocytes which undergo meiotic division to form secondary spermatocytes and spermatids.
- Eventually spermatids differentiate into mature sperms.
- The sperms are then transferred to the main duct of the male reproductive tract, the vas deferens, which forms highly convoluted epididymis.
- The sperms then pass through the urinogenital duct and are discharged out.

POINT TO PONDER



(a) Gamete formation in the male

Hormonal Regulation of Spermatogenesis

In males, the hormonal regulation of spermatogenesis is listed in the following table.

Hormone	Source	Physiological Effects
GnRH	Hypothalamus	• Stimulate the anterior pituitary gland to release gonadotrphins
FSH	Anterior pituitary lobe	• Enhances sperm formation
LH/ICSH	Anterior pituitary lobe	• Stimulate interstitial cells of testis to produce testosterone
Testosterone	Interstitial cells in testes	• Spermatogenesis • Development and maintenance of male reproductive structures • Male secondary sexual characteristics • Sex drive
Inhibin	Sertoli cells in testes	• Inhibits FSH secretion, thus causing a decrease in sperm and testosterone production

FEMALE REPRODUCTIVE SYSTEM

Gonads

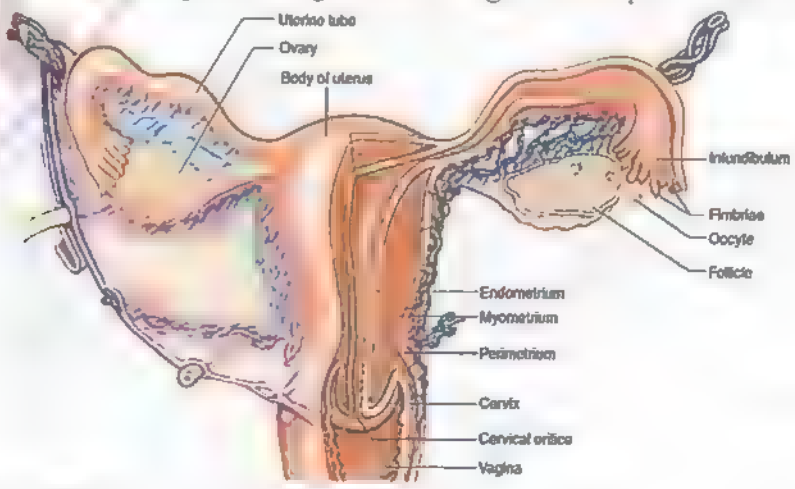
- Female gonads are ovaries which lie within the body cavity of the female and held by several ligaments.
- Germ cells in the ovary produce many oogonia.

External Genitilia

- Structures external to **vagina** constitute external genitalia in female.

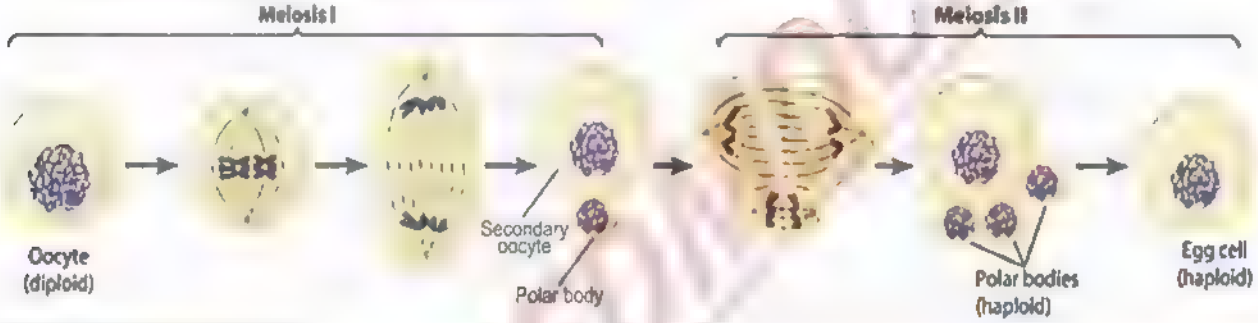
Associated Ducts

- Discharge of ovum from ovary is called **ovulation.**
- Main duct of female reproductive tract is oviduct that is also called as uterine tube or fallopian tube.
- Fertilization of ovum occurs in **proximal part of oviduct.**
- Oviduct leads to uterus. It is about the size and shape of an inverted pear. Uterus has role in implantation/ conception, placentation and development. Innermost layer of uterus is endometrium, middle myometrium and outermost is perimetrium.
- Uterus opens into the vagina through cervix. Vagina is the part of birth canal.



Oogenesis

- Gametogenesis in the female is known as oogenesis and result in the formation of ova/egg.
- Oogenesis starts before birth when oogonia divide mitotically to produce primary oocytes.
- These primary oocytes are enclosed in groups of follicle cells.
- Primary oocytes undergo through meiosis I but are arrested at prophase I.
- At puberty, primary oocyte completes meiosis I and gives rise to haploid secondary oocyte along with 1st polar body.
- Secondary oocyte undergoes through meiosis II but arrested in Metaphase II. It is released in this stage from ovary and does not proceed further until fertilized.
- If fertilization occurs, then secondary oocyte divides to form ovum and 2nd polar body.
- In human female only one ovum is usually discharged from the ovary at one time, this phenomenon is called ovulation.



(b) Gamete formation in the female

Overview/Summery of Gametogenesis in Humans

Feature	Spermatogenesis	Oogenesis
Location	Occur in testes	Occur mainly in ovaries
Meiotic Division Results in	Equal division of cytoplasm	Unequal division of cytoplasm
Number of Gametes Produce	Four	One and two to three polar bodies
Size of the Gamete	Relatively smaller	Relatively larger
Duration	Un-interrupted process	In arrested stages
Onset	Begins at puberty	Begins during fetal life
Release of gametes	Continuous	Monthly (From puberty
End	Lifelong (But reduces with age)	Terminates with menopause
Growth phase	Short	Prolonged
Gamete Motility	Yes	No

MENSTRUAL CYCLE

- In female, production of egg is a cyclic activity as compared to male.
- Oestrous cycle is reproductive cycle in all mammalian female except humans. In human female, it is called menstrual cycle.

Feature	[illegible]	[illegible]
Occurrence	All mammals except human	Human female
Release of Oestrogen	At low level	At higher level
Preparation of Uterus	Partial for conception	Fully for conception
If fertilization does not occur	Resorption of endometrium	Destruction and discharge (Menstrual flow)
	Egg is conserved	Egg is released
Ovulation	Requires physical stimulus of mating	Under hormonal control

POINT TO PONDER

- Menstrual cycle involves changes in the structure and function of the whole reproductive system.
- 1st ovulation and menstruation occur at puberty. Start of menstrual cycle is called menarche. Its complete stop or end is called menopause.
- It is completed in approximately 28 days.
- The events of the menstrual cycle involve the ovaries (ovarian cycle) and the uterus (uterine cycle).
- Events of menstrual cycle are regulated by pituitary gonadotrophins.
- Menstrual cycle can be divided into four phases.

Phases and Events of Menstrual Cycle

(i) Pituitary gland on the onset of puberty, releases FSH which stimulates the development of several primary follicles. Only one of these follicles continues to grow with its primary oocyte while the rest breakdown by a degenerative process known as **follicle atresia**.

(ii) Ovary under influence of FSH produces estrogen.

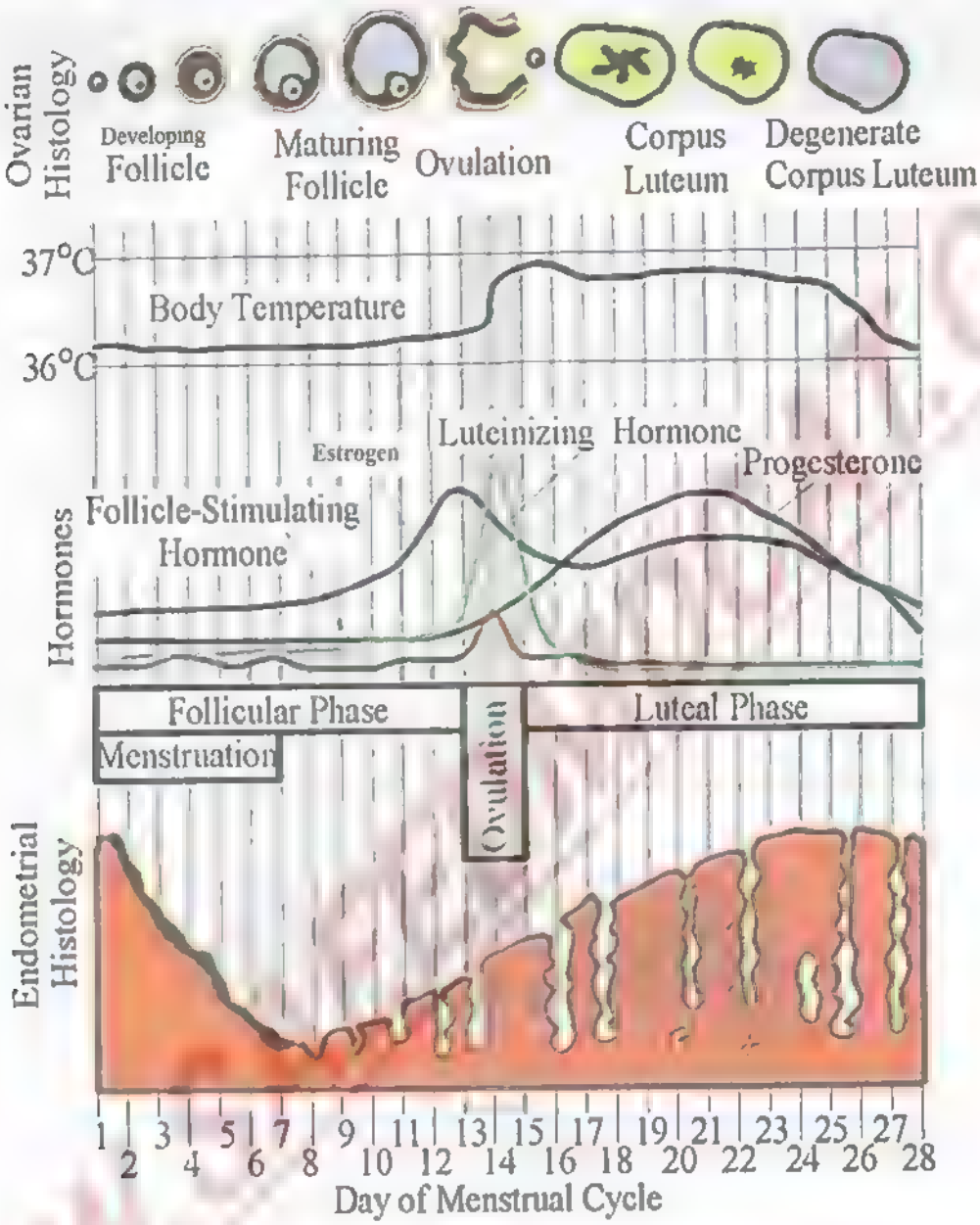
(iii) Estrogen, on one hand, stimulates the endometrium and vascularizes it. On the other hand, it inhibits secretion of FSH.

(iv) Decrease of FSH and increase of estrogen, causes the pituitary gland to secrete LH which induces ovulation.

(v) The follicle cells, after release of egg, are modified to form a special structure called corpus luteum. This yellowish glandular structure starts secreting progesterone, which develops endometrium and makes it receptive for implantation and placentation.

POINT TO PONDER

(vi) If fertilization does not occur, the corpus luteum starts degenerating. The progesterone secretion diminishes and its supporting effect on the spongy endometrium is reduced, which suffers a breakdown. This causes the discharge of blood and cell debris known as menstruation. This stage usually lasts for 3-7 days.



SEXUALLY TRANSMITTED DISEASES

Feature	Gonorrhea	Syphilis	Herpes	[illegible]
Causative Agent	Gram positive bacteria	Spirochete	Virus	Virus
Cause	*Neisseria gonorrhoeae*	*Treponema pallidum*	Herpes simplex type II	HIV
Main parts Affected	Mucous membrane of urinogenital tract, eye infection to baby.	Damage to reproductive organs, eyes, bones, joints, CNS, heart, skin.	Infection of genitilia, genital soreness & ulcers, damage to eyes & CNS in infants.	Destruction of immune system
Source of Transmission	Sexual contact	Sexual contact	Sexual contact	Sexual contact
Treatment	Antibiotics	Antibiotics	Anti-viral	Anti-viral

POINT TO PONDER

TOPIC-15 VARIATION & GENETICS / INHERITANCE

COURSE CONTENT

- Basic Terms
- Mendelian Inheritance
- Law of Segregation
- Law of Independent Assortment
- Dominance Relations
- Multiple Alleles (ABO Blood Group System)
- Rh Blood Group System
- Maternal Fetal Rh incompatibility
- Epistasis and Bombay Phenotype
- Polygenic Inheritance
- Gene Linkage and Crossing Over
- Recombination Frequency and Genetic Map of Chromosome
- Patterns of Sex Determination
- Sex Linkage in *Drosophila*
- Sex Linkage in Humans (Hemophilia and Colour Blindness)

BASIC TERMS

Gene

- It is the basic unit of biological information.
- Genes are actually parts of DNA comprising its basic sequence.
- It is sequence of nucleotides that specifies sequence of amino acids in a polypeptide chain.

Locus

- The position of a gene on the chromosome is called its locus.

Allele

- Genes form pairs on pairs of homologous chromosomes.
- One member of a gene pair is located on one homologue and the other member on the other homologue.
- Partners of a gene pair are called alleles.
- Each allele of a gene pair occupies the same gene locus on its respective homologue.
- Both alleles on one locus may be identical or different from each other.

Dominant Allele

- Such an allele that masks the effect of other allele in a pair is called dominant allele and such trait is called dominant trait.
- For example, in pea plant, round (R) is dominant over wrinkled (r).

Recessive Allele

- Such an allele that is masked by another allele in a gene pair is called recessive allele and such trait is called recessive trait.
- For example, in pea plant, green (y) is recessive while yellow (Y) is dominant

Gene Pool

- All the genes alleles found in a breeding population at a given time are collectively called the gene pool.
- It consists of all the alleles at all genes loci in all individuals of the population.

- For a diploid species, each locus is represented twice in a genome of the individual who may be either homozygous or heterozygous.

Phenotype

- Physical appearance of a trait is called phenotype.
- For example, round and wrinkled are phenotypes of seed shape as the shape is a trait.

Genotype

- Genotype is the genetic complement i.e. the genes in an individual for a particular trait.
- For example, genotype of AB blood group is I^AI^B.

Homozygous

- When both alleles of a gene pair in an organism are same, the organism is homozygous for that gene pair.
- An individual with homozygous genotype is called homozygote or true breeding.
- For example, RR is genotype of homozygous round seeded pea plant.

Heterozygous

- If both alleles of a gene pair are different from each other, the organism is heterozygous for that gene pair.
- An individual with heterozygous genotype is called heterozygote or hybrid.
- For example, Rr is genotype of heterozygous round seeded pea plant.

Selection of Pea Plant

Mendel selected pea plant (*Pisum sativum*) as experimental material due to following reasons:

- Its flowers were hermaphrodite. It was normally self-fertilizing but could be cross fertilized.
- It has short generation time.
- It has many sharply distinct traits.

Selection of Pea Plant

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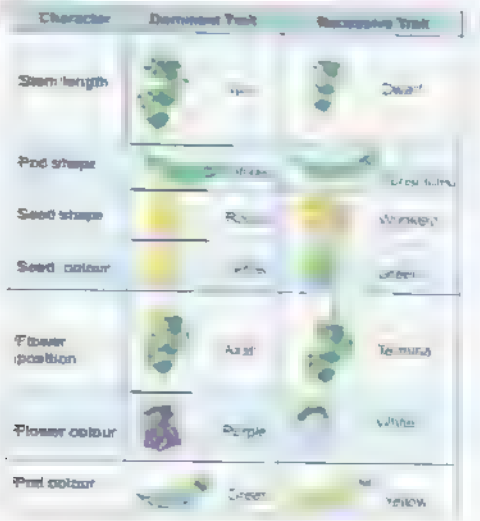
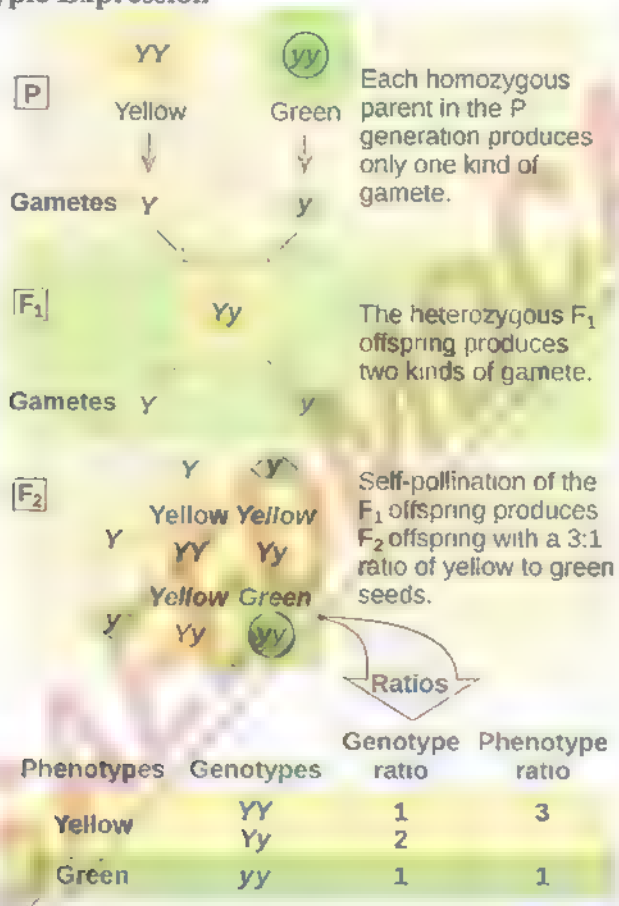
Contrasting Traits Studied by G. Mendel



Introduction

- According to law of segregation, 'the two co-existing alleles for each trait in an individual segregate (separate) from each other at meiosis, so that each gamete receives only one of the two alleles. Alleles unite again at random fertilization of gametes when zygote is formed'.
- Law of segregation was developed through **monohybrid cross** (varying in one trait).

Phenotypic and Genotypic Expression



Phenotypes	Genotypes	Genotype ratio	Phenotype ratio
Yellow	YY	1	3
	Yy	2	
Green	yy	1	1

Results

- Yellow is dominant over green.
- Phenotype ratio of F_2 generation is 3:1.
- Genotype ratio of F_2 generation is 1:2:1.

Test Cross

It is a mating in which an individual showing a dominant phenotype is crossed with an individual showing its recessive phenotype.

Significance

This cross finds out the homozygous or heterozygous nature of the genotype.

Details

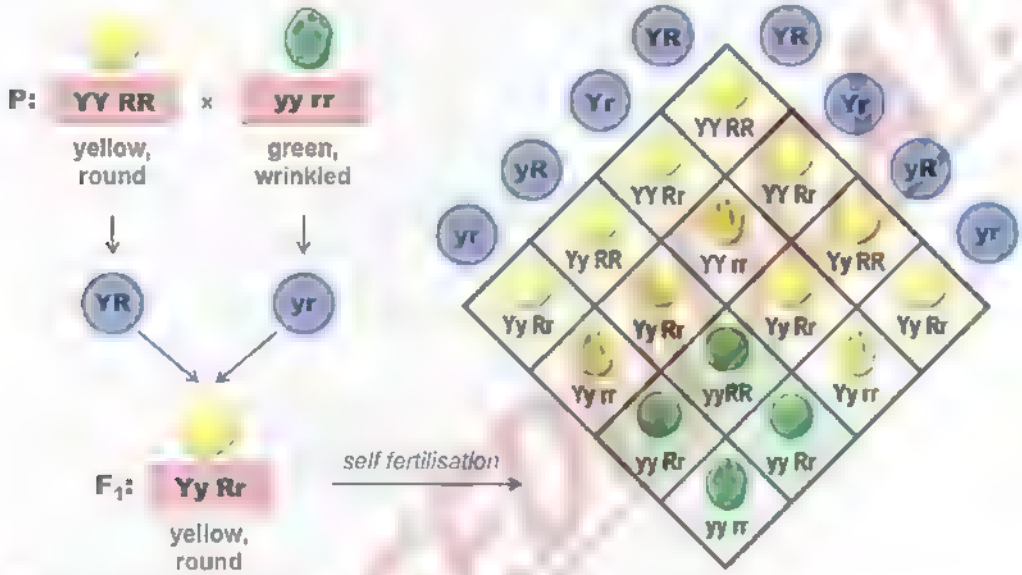
- If round is crossed with wrinkled seeded plant and all offspring are round seed producing, then round of P_1 will be homozygous.
- If round is crossed with wrinkled seeded plant and offspring are obtained in 1:1 then round of P_1 will be heterozygous.

LAW OF INDEPENDENT ASSORTMENT

Introduction

- Law of independent assortment is stated that 'when two contrasting pairs of traits are followed in the same cross, their alleles assort independently into gametes'.
- The distribution of alleles of one trait into gametes has no influence on the distribution f alleles of the other trait.
- Law of independent assortment was developed by studying dihybrid crosses (varying in two traits).

Phenotypic & Genotypic expression



Probability and Product Rule

- Probability is the chance of an event to occur e.g. in F_2 offspring of a monohybrid cross the independent chance for a seed to be round is 3/4.
- When two independent events are occurring simultaneously like in dihybrid cross, the ratio of each joint phenotypic combination can be obtained by multiplying the probabilities of individual phenotypes. It is called product rule

Event No. 1 Seed Shape Independent Probability	Event No. 2 Seed Colour Independent Probability	Both Events at a Time Seed Shape & Colour Joint Probability
Round = 3/4	Yellow = 3/4	Round Yellow = 3/4 x 3/4 = 9/16
Round = 3/4	Green = 1/4	Round Green = 3/4 x 1/4 = 3/16
Wrinkled = 1/4	Yellow = 3/4	Wrinkled Yellow = 1/4 x 3/4 = 3/16
Wrinkled = 1/4	Green = 1/4	Wrinkled Green = 1/4 x 1/4 = 1/16

Limitations of Law of Independent Assortment

- Genes are located on chromosomes at specific loci. Independent assortment of genes depends upon independent assortment of their chromosomes.
- All the genes present on a homologous pair of chromosomes are linked to each other in the form of a linkage group. These cannot assort independently.
- Those alleles assort independently whose alleles are riding non-homologous chromosomes

DOMINANCE RELATIONS

- It is a physiological effect of an allele over its partner allele on the same gene locus.
- There are four types of dominance relations:

Feature	Complete Dominance	Incomplete Dominance	Co-dominance	Over Dominance
Alleles in Heterozygote	One allele completely masks effect of other.	Both alleles are expressed partially.	Both alleles are expressed fully.	One allele boosts effect of other allele.
Phenotype of Heterozygote	Resembles with one homozygote	Intermediate between both homozygotes	Distinct from both homozygotes.	Exceeds in quantity from homozygote.
Expression of Alleles	Capital letter for dominant and small letter for recessive.	Different expression e.g. R1 and R2	Different expression e.g. M and N	Different expression for dominant and recessive e.g. w+ and w.
Phenotype & genotype Ratios	Different	Same	Same	Same
Need of Test Cross	✓	×	×	×
Examples	All seven traits studied by Mendel	Flower colour in 4 O'clock plant	AB and MN blood groups	Eye colour of *Drosophila*

MULTIPLE ALLELES (ABO BLOOD GROUP SYSTEM)

- All such altered alternative forms of a gene, whose number is more than two are called multiple alleles.
- Some genes may have as many as 300 alleles.
- Any two of these multiple alleles can be present in the genome of a diploid organism, but a haploid organism or a gamete has just one of them in its genome.
- Gene mutations may produce many different alleles of a gene.

Abo Blood Group System

- ABO blood group is first discovered multiple allelic blood group system in man.
- This blood group system is encoded by a single polymorphic gene I on chromosome 9. It has three multiple alleles I^A, I^B and i.
- Allele I^A specifies production of antigen A, allele I^B specifies production of antigen B but allele I_0/i does not specify any antigen.
- Alleles I^A and I^B are co-dominant for each other while completely dominant over i.

Phenotypes & Genotypes

Phenotype	Genotype	Antigen	Antibody
A	I^AI^A, I^Ai	A	Anti-B antibody
B	I^BI^B, I^Bi	B	Anti-A antibody
AB	I^AI^B	A & B	No Antibody
O	ii	No	Anti-A antibody Anti-B antibody

Blood Transfusion

Blood Group	Donated To	Receives From
A	A, AB	A, O
B	B, AB	B, O
AB	AB	A, B, AB, O
O	A, B, AB, O	O

[illegible]

- Positive or negative sign of blood group refers to the presence or absence of another blood group system antigen called Rh factor.
- Rh blood group system is defined on the basis of Rh factor present on the surface of RBCs.
- Rh blood group system is encoded by three genes C, D and E which occupy two tightly linked loci.
- Alleles of gene D occupy one locus called locus D, while genes C and E alternatively occupy the other locus. The D locus is of prime importance.
- Gene D has two alleles, D and d. D is completely dominant over d.

Phenotypes & Genotypes

Phenotype	Genotype	Antigen	Antibody
Rh positive	DD, Dd	Present	Absent
Rh negative	dd	Absent	Absent

Blood Transfusion

Blood Group	Donated To	Receives From
Rh positive	Rh positive	Rh positive Rh negative
Rh negative	Rh positive Rh negative	Rh negative

MATERNAL FETAL RH INCOMPATIBILITY

Introduction

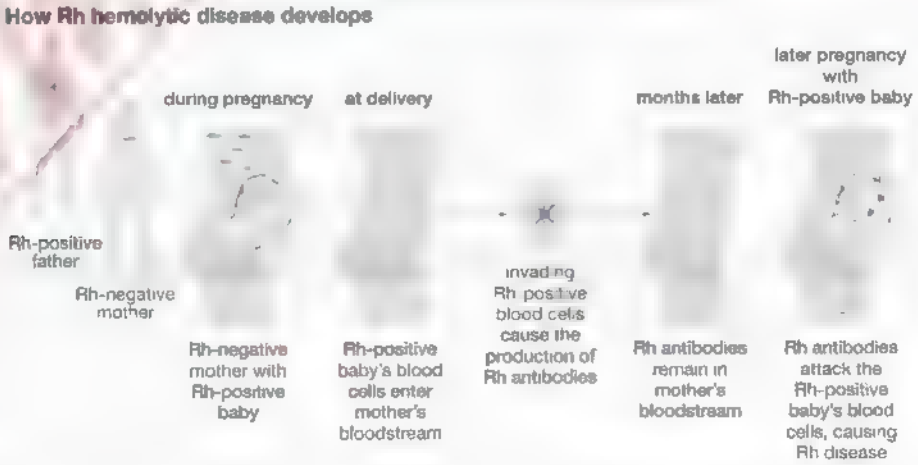
It results when a Rh⁻ woman, married to a Rh⁺ man, conceives a child who is Rh⁺.

Chances

- If the man's genotype is DD, all of their offsprings (Dd) will be Rh^+.
- If the man's genotype is Dd, half of their offspring with Dd genotype will be Rh^+.

Mechanism

Different steps involved are shown in the following diagram.



- Anaemia may lead to abortion or still birth.
- If pregnancy continues, the liver and spleen of the foetus swell as they rapidly produce RBC.
- The breakdown product of RBC called bilirubin also accumulates in foetus. Bilirubin damages his brain cells and turns his skin and whites of eye yellow. This condition is called **jaundice**.

Control of Incompatibility

- Rh sensitization of Rh mother is avoided by a simple therapy. She is given an injection of Rh antiserum during early pregnancy and immediately after birth. The Rh–antibodies in the Rh antiserum will destroy Rh^+ RBC of the foetus before they stimulate production of maternal anti Rh antibodies. The injected antiserum disappears before the next pregnancy.
- Sometimes a mild ABO incompatibility protects the baby against a more severe Rh incompatibility. If O^- mother conceives A^+ or B^+ baby, any foetal A or B type RBC entering the mother's blood are quickly destroyed by her anti-A or anti-B antibodies, before she can form anti-Rh antibodies.

EPISTASIS AND BOMBAY PHENOTYPE

Definition

When an effect caused by a gene or gene pair at one locus interferes with or hides the effect caused by another gene or gene pair at another locus, such a phenomenon of gene interaction is called **epistasis**.

- Epistasis must not be confused with dominance **Dominance** is the relationship between alleles of the same gene occupying the same locus, but epistasis is the interaction between different genes occupying different loci.

Bombay Phenotype

Bombay phenotype is an example of epistasis. Such a blood phenotype which is different from genotype is called Bombay phenotype.

Mechanism

The expression of ABO blood type antigens by I^A or I^B gene depends upon the presence of another gene H.

(i) ABO locus is on chromosome 9.

(ii) H locus is on chromosome 19.

- 'H gene' (dominant) changes a precursor substance into 'substance H'.
- It produces an enzyme that inserts a sugar onto a precursor glycoprotein on the surface of RBC.
- Antigen A or antigen B specified by I^A or I^B gene could attached to this sugar of substance H

The 'recessive allele h' cannot insert sugar molecule to glycoprotein. Therefore, 'hh' individuals lack the site of attachment for antigen A or antigen B. Their RBC lack A and B antigens although they do not lack I^A and I^B genes. They are phenotypically like O but are not genotypically O.

POLYGENIC INHERITANCE

- A **continuously varying trait** is encoded by alleles of two or more different gene pairs found at different loci, all influencing the same trait in an additive way.
- Qualitative differences are large and more obvious but quantitative differences are small and less striking.

- A continuously varying trait is encoded by alleles of two or more different gene pairs found at different loci, all influencing the same trait in an additive way. Those quantitative traits are called **polygenic traits** and their genes are **polygenes**.
- **Human skin color** is controlled by 3-6 gene pairs.
- **Tongue rolling** is quantitative trait controlled by single dominant gene.
- **Multifactorial traits** are controlled both by genes and environment.

Phenotypes of wheat grain color

Genotype	Phenotype
AABBCC	Dark red
Aabbcc	White
Aabbcc/ aaBbcc/ aabbCc	Light pink
AAbbcc/ aaBBcc/ aabbCC/ AaBbcc/ aaBbCc/ AabbCc	Pink
AaBbCc/ AABbcc/ AabbCC	Light red
AABBcc/ aaBBCC/ AAbbCC	Red
AABBCc/ AABbCC/ AaBBCC	Moderately dark red

GENE LINKAGE AND CROSSING OVER

Gene Linkage

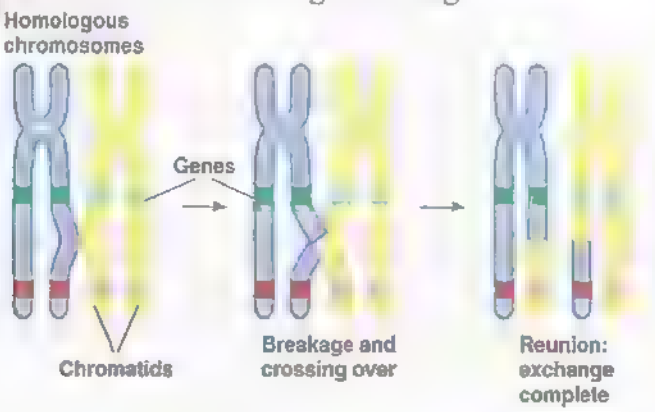
- Phenomenon of staying together of all the genes of a chromosome is called gene linkage.
- Gene linkage is a physical relationship between genes.
- A chromosome carries its linked genes en block in form of linkage group.
- The number of linkage groups corresponds to the number of homologous pairs of chromosomes. Man has 23 linkage groups.

Examples

- Genes for colour blindness, haemophilia, gout etc. form one linkage group on human X chromosome.
- Gene for sickle cell anaemia, leukemia and albinism etc. form linkage group on human chromosome 11.

RECOMBINATION FREQUENCY AND GENETIC MAP OF CHROMOSOME

- **Crossing over** is an exchange of segments between non-sister chromatids of homologous chromosomes during meiosis.
- Linked genes can be separated by crossing over Closer the two gene loci, more strongly their genes linked. The farther apart two genes lie; greater are chances of their separation through crossing over.
- Crossing over minimizes the chances of gene linkage.



- **Cross over or recombination frequency** is the proportion of recombinant types between two gene pairs as compared to the sum of all combinations.
- The recombination frequencies between two linked genes can be calculated by backcrossing the heterozygote to a homozygote double recessive.
- Its value is directly proportional to distance between the linked gene loci. Genes can be mapped on a chromosome on the basis of their recombination frequencies

PATTERNS OF SEX DETERMINATION

Sex Chromosomes

- Chromosomes which are different in male and female and have genes for determination of sex are called sex chromosomes.
- All chromosomes other than sex chromosomes are called autosomes. Autosomes do not carry any sex determining gene.

Humans as Example

- Humans have 46 chromosomes in form of 23 pairs.
- 22 pairs are of autosomes and one pair is of sex chromosomes.
- Autosome pairs are common in both the sexes but 23rd sex chromosome pair is very different in male and female.
- A female has two similar X chromosomes in her 23rd pair but a man has an X chromosome along with a much shorter Y chromosome in his 23rd pair.
- The 23rd pair in man is heteromorphic. She is XX but he is XY.
- SRY is the male determining gene. It is located at the tip of short arm of Y chromosome. It is male sex switches and expressed during 6th week of pregnancy.

Patterns of Sex Determination

Examples	Grasshopper, *Protenor bug*	Human, *Drosophila*	Birds, Butterflies, Moths
Male	XO	XY	ZZ
	Heterogametic	Heterogametic	Homogametic
Female	XX	XX	ZW
	Homogametic	Homogametic	Heterogametic
Sex Determining Gamete	Sperm	Sperm	Egg
Sex Ratio	1:1	1:1	1:1

SEX LINKAGE IN DROSOPHILA

- T. H. Morgan (1910) provided experimental evidence in support of chromosomal theory of heredity through discovery of sex linkage in *Drosophila*.

Reasons for Selection of Drosophila

Drosophila is a very useful organism for genetic studies for many reasons. For example;

(i) Easy collection & culturing
(i) Sexual dimorphism
(ii) Short generation time
(iii) Excellent for genetic studies
(iv) Part of human genome project

Morgan's Experiments and Crosses

- Morgan raised cultures of *Drosophila* flies to study different traits, such as colour of the eye.

- Normal fruit flies, the **wild type,** have bright red eyes. One of his coworkers Calvin Bridges, observed an unusual white eye mutant male fly.

Step 1: Normal Cross

Morgan mated white eyed male with a wild type red eyed female. All 1237 offspring of this cross had red eyes. Morgan concluded that red eye is dominant trait.

Step 2: Normal Cross

Morgan allowed males and females of F_1 generation to mate and produce F_2 generation. He counted 2459 red eyed females, 1011 red eyed males and 782 white eye males among F_2.

Observations

Different observations got by this cross were;

- Offspring produced due to this cross were red-eyed females, red-eyed males and white-eyed males.
- The proportion of 3470 red eyed to 782 white eyed flies did not perfectly fit into Mendelian 3:1 ratio.
- The number of recessive phenotype individuals was too small.
- All the white-eye flies were only males. There was no white eye female in F_2

Conclusion

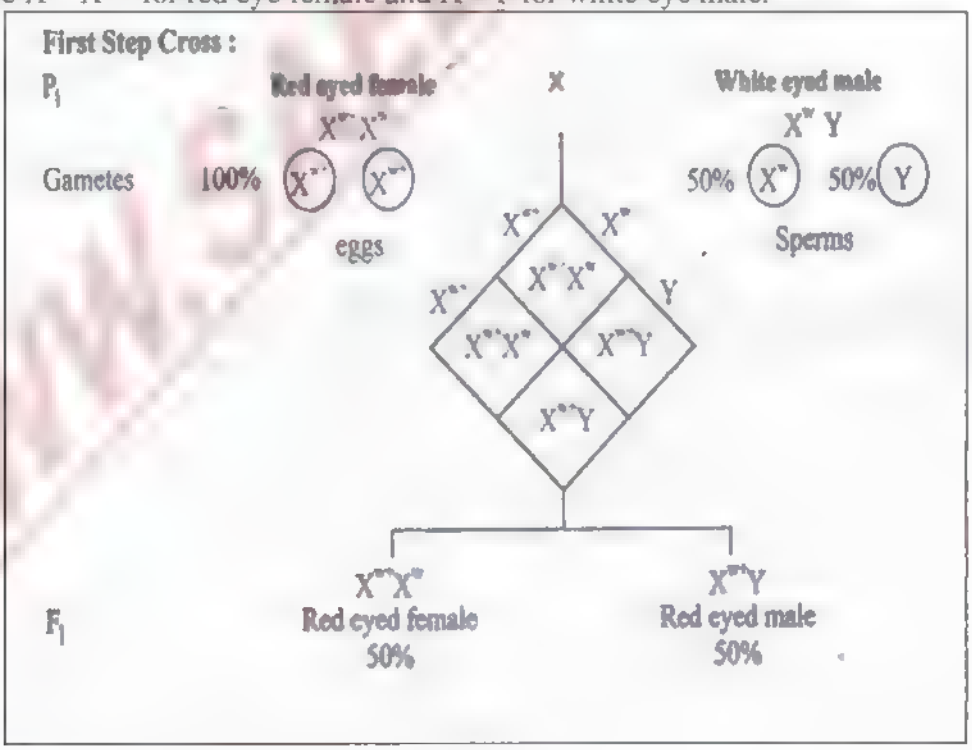
The inheritance of eye color somehow seemed to be related to the sex of offspring. Morgan proposed that;

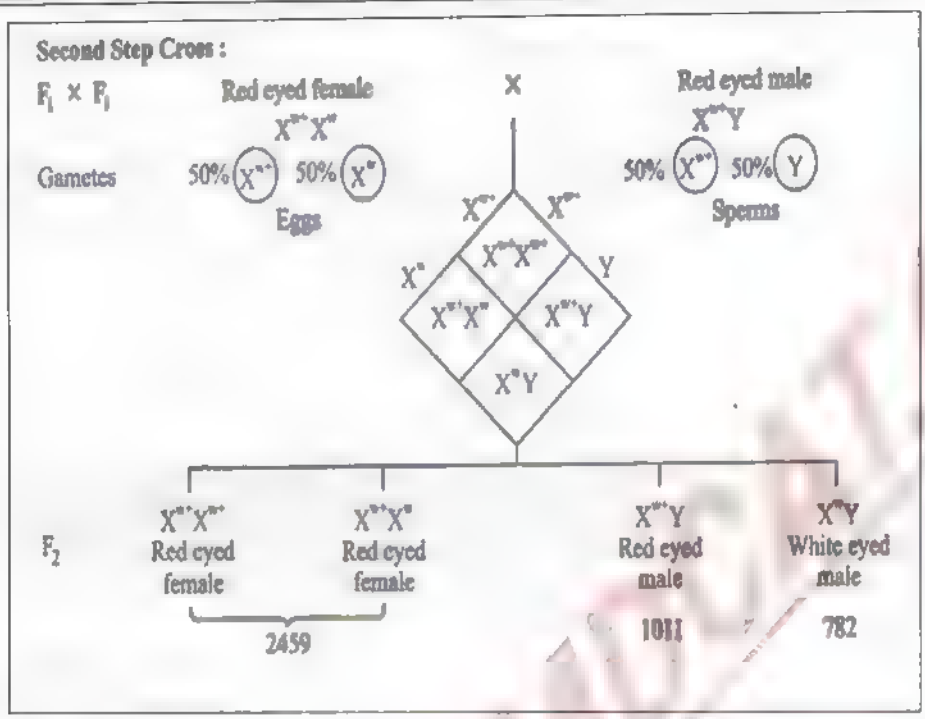
(i) The gene for eye color is located on X-chromosome.

(ii) The alleles for eye color are present only on X-chromosome. There is no corresponding allele for this trait on Y-chromosome.

(iii) Single recessive allele on X-chromosome can express itself in males because Y-chromosome is empty for that gene.

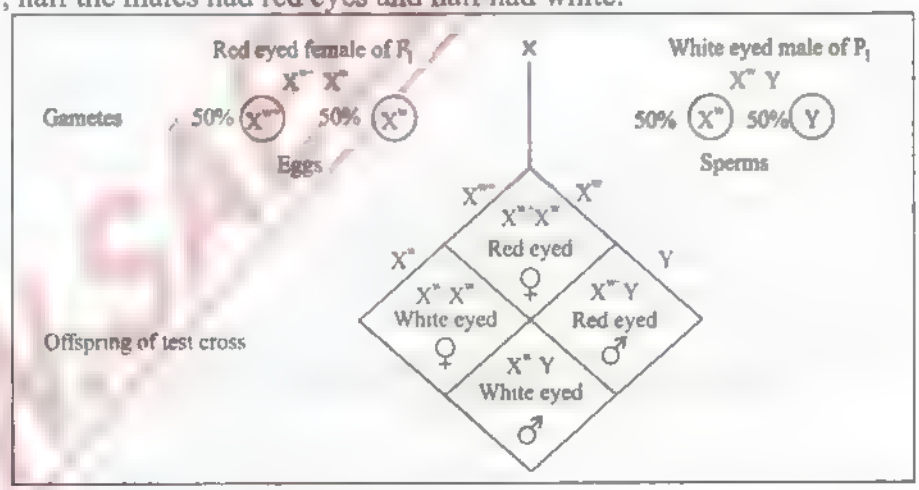
- Now we can relate these crosses with genotype. The genotype of the parents of P_1 cross were $X^{W}X^{W}$ for red eye female and $X^{W}Y$ for white eye male.





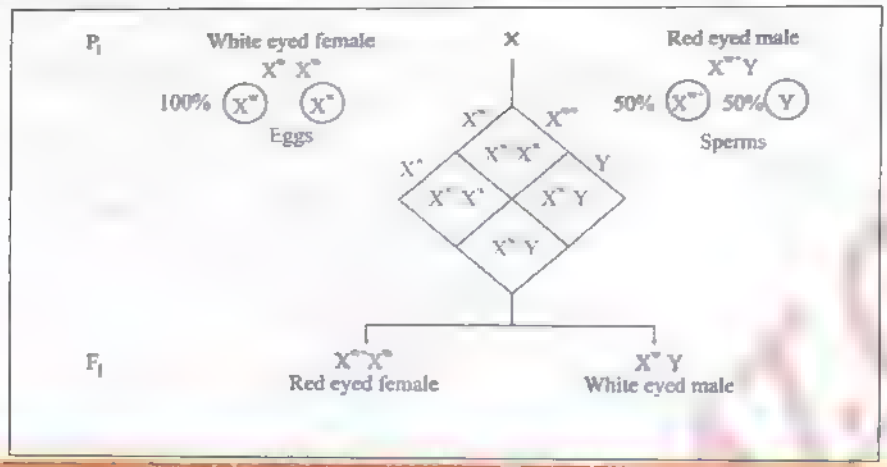
Step 3: Test Cross

- Morgan wanted to test his hypothesis. He crossed the P_1 white eyed male (X^wY) with one of its own daughters (the red-eyed heterozygous female from F_1 generation).
- Out of total offspring of this cross, half female offspring had red eyes and half had white. Similarly, half the males had red eyes and half had white.



Step 4: Reciprocal Cross/ Confirmatory Test

- Appearance of white eyed female provided an opportunity for a further confirmatory test.
- Morgan mated a white-eyed female with a red-eyed male. All female offspring had red eyes and all male offspring had white eyes.
- When F_1 red-eyed females and white-eyed males were mated to produce F_2, then half of the F_2 females had red eyes and half white eyes.
- Similarly, half of the F_2 males had red eyes and half white. This F_1 x F_1 cross was exactly like step 3 test cross.



SEX LINKED INHERITANCE (HAEMOPHILIA, COLOUR BLINDNESS)

- A trait whose gene is present on X chromosome is called **X-linked trait** X-linked traits are commonly referred as sex-linked traits.
- **X-linked recessive traits** are common in male while **X-linked dominant traits** are common in female.
- X-linked traits follow **zig zag path** while Y-linked traits are transmitted in **straight way**.
- Genes located on Y chromosomes are called Y-linked genes and their traits are called **Y-linked traits**.
- Such traits whose genes are located on both X & Y chromosomes are called X & Y linked or **pseudoautosomal traits** such genes are called X-and-Y linked genes.

Haemophilia

- It is a rare X-linked recessive trait.
- Haemophiliac's blood fails to clot properly after an injury, because it has either reduction or malfunction or complete absence of blood clotting factors.
- It is a serious heredity disease because a haemophiliac may bleed to death even from minor cuts.

Types of Haemophilia

Type	Occurrence	Factor	Genetic
A	80%	VIII	X-linked recessive
B	20%	IX	X-linked recessive
C	Less than 1%	XI	Autosomal recessive

- Haemophilia A and Bare non-allelic recessive sex-linked but haemophilia C is an autosomal recessive trait (Autosome 4).
- Haemophilia A and B have more chances in male as compared to female while haemophilia C has equal chances in both male and female.

Genetics of Haemophilia A

- A woman can suffer from 'haemophilia A' only when she is homozygous for the recessive allele.

- A man with just one recessive allele will display the trait.
- Haemophilia A zig-zag from maternal grandfather through a carrier daughter to a grandson.
- It never passes direct from father to son.
- Gene for normal is H and gene for 'haemophilia A' is h.

Gender	Genotype	Phenotype
Female	X^HX^H	Normal
	X^HX^h	Normal but Carrier
	X^hX^h	Haemophilic
Male	X^HY	Normal
	X^hY	Haemophilic

Colour Blindness

- Normal trichromatic colour vision is based on three different kinds of cone cells in the retina, each sensitive to one of the three primary colours red, green or blue.
- Each type of cone cell has specific light absorbing proteins called opsins.

Genetics

- The genes for red and green opsins are on X chromosome while the gene for blue opsin is present on autosome 7.

Types of Colour Blindness

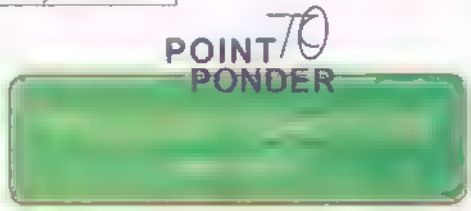
- Mutations in opsin genes cause three types of colour blindness:

(i) Dichromacy

- A dichromatcan perceive two primary colours but is unable to perceive one whose opsins are missing due to mutation.
- It is further categorized into three following types:

	Blindness	Perception
Protanopia	Red blindness	Green, Blue
Deuteranopia	Green blindness	Red, Blue
Tritanopia	Blue blindness	Red, Green

(ii) Protanomalous



- Some people can detect red and green but with altered perception of the relative shades of these colours.
- They have abnormal but still partially functional opsins.
- They are protanomalous and deuteranomalous for red and green weakness respectively.

(iii) Monochromacy

- A monochromat can perceive only one colour. Monochromacy is true colour-blindness.
- **Blue cone monochromacy** is an x-linked recessive trait in which red and green cone cells are absent.
- It is a common heredity disease.

- Like any sex-linked recessive traits, it also zigzags from maternal grandfather through a carrier daughter to a grandson.
- It never passes direct from father to son.
- This type of colour blindness is more common in men than women, because chances for a male to be affected by it are much more than a female.

Others

- **Testicular feminization syndrome** is a rare X-linked recessive trait in which person has X & Y chromosomes yet tfm genes on their X-chromosome develops them physically into female.
- A **sex-limited trait** is limited to only one sex due to anatomical differences e.g. beard growth in human male and milk yield in cows.
- **Sex influenced traits** occur in both males and females, but they are more common in one sex e.g. pattern baldness. These are influenced by hormonal differences.

Traits and Examples

Trait	Example
X-linked recessive	Hemophilia, colorblindness, testicular feminization syndrome
X-linked dominant	Hypophosphatemic or vitamin D resistant rickets
Y- linked trait	Maleness
Pseudoautosomal trait	Bobbing in insects
Sex limited trait	Milk yield in cow, beard in man
Sex influenced trait	Baldness

TOPIC-16 » CHROMOSOME & DNA

CONTENTS

- Chromosomes (Number, Structure, Composition and Organization)
- Chromosomal Theory of Inheritance
- Concept of Gene
- DNA as Hereditary Material
- Models of DNA Replication
- Meselson-Stahl's Experiment
- Process of DNA Replication
- Central Dogma of Gene Expression
- Transcription
- Genetic Code
- Translation
- Mutation

CHROMOSOMES (NUMBER, STRUCTURE, COMPOSITION AND ORGANIZATION)

- **Chromosomes** are thread like structures that appear inside the nucleus at the time of cell division.
- Chromosomes were first observed by the German embryologist **Walther Fleming** in 1882, in cells of salamander larvae.
- **Human cells** have 46 chromosomes, consisting of 23 pairs.

Mosquito	6
Honeybee	32
Corn	20
Sugarcane	80
Frog	26
Mouse	40

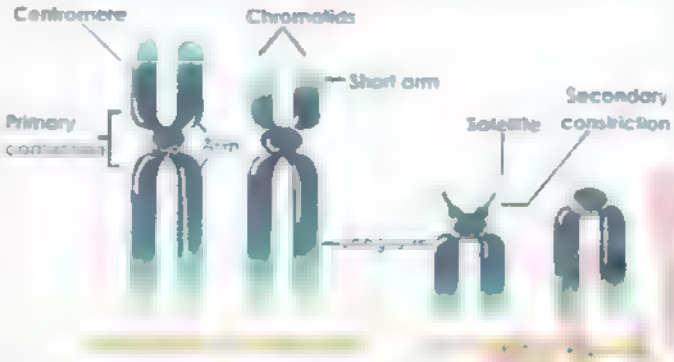
Structure and Types

- Generally, both chromatids are attached with each other at a point known as **centromere** or **primary constriction**, so each chromosome shows two **arms**.
- Some chromosomes may have another point of union along the length of chromatids, called **secondary constriction**.
- Beside secondary constriction the end becomes a knob like structure called **satellite**.
- This region has a useless sequence of DNA called junk DNA
- **Karyotype** is the particular array of chromosomes that an individual possesses.

Type	Position of Centromere	Shape
Metacentric	In the center	V-shaped
Sub-metacentric	Slightly away from the center	J-shaped
Acrocentric	Near the end	I-shaped
Telocentric	At an end	I-shaped

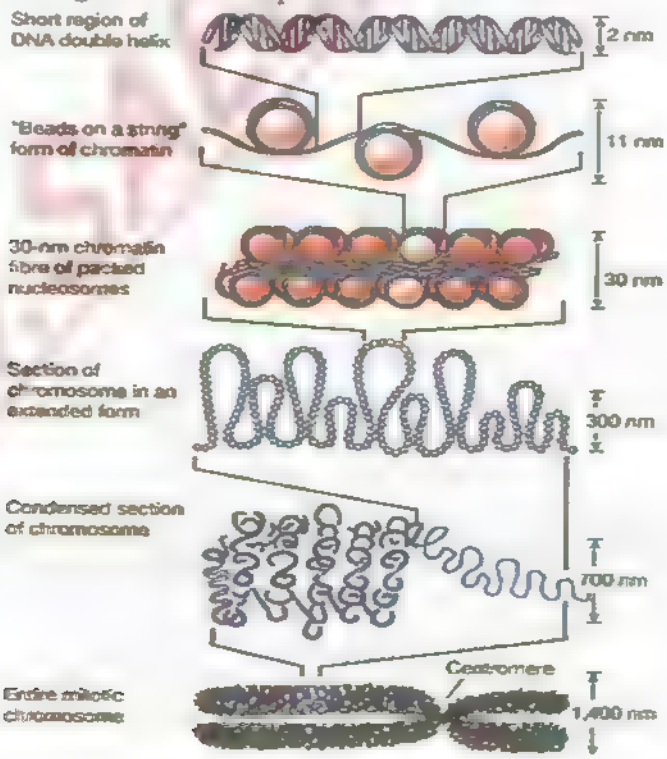
Telomere

- A **telomere** is a region of repetitive nucleotide sequences at each end of a chromosome.
- It protects the end of the chromosome from deterioration or from fusion with neighboring chromosomes.
- Telomeres are the caps at each end of DNA that protects chromosomes like the plastic tips at the end of shoelaces.



Composition of Chromosomes

- Chromosomes are composed of **DNA (40%)** and **proteins (60%).** A significant amount of RNA is also associated with chromosomes.
- A typical human chromosome contains about 140 million (1.4×10^8) nucleotide in its DNA.
- A **nucleosome** is composed of eight histone proteins and coiled DNA duplex.
- Histones are positively charged due to abundance of basic amino acids, arginine and lysine.
- Highly condensed portions of the chromatin are called **heterochromatin**.
- **Euchromatin** is condensed only during cell division and at other times it is in open configuration and its genes can be expressed.



CHROMOSOMAL BASIS OF INHERITANCE

The chromosomal theory of inheritance is the idea that **"genes, the units of inheritance, are found on the chromosomes, so chromosomes act as carriers of heredity"**.

- Emergence or origin of chromosomal theory of inheritance is linked with discovery of chromosomes which were first observed by Walther Fleming.
- The term **"chromosome"** was proposed by Waldeyer, which literally means colored bodies.
- First time the relationship of heredity units with chromosomes was put forward by Karl Correns.
- The actual credit of this theory goes to both Walter Sutton and Theodor Boveri.
- In 1902, these scientists recognized independently that the behavior of Mendel's factors (genes) is parallel to the behavior of chromosomes at meiosis.
- If Mendel's model is correct, then these two gametes must make equal hereditary contributions. Sperm, however, contains little cytoplasm and during fertilization it only contributes nucleus to the zygote.
- Therefore, the hereditary units must reside within the nucleus of the gametes.
- Genes would be present in chromosomes.
- Many investigators of that time pointed out a serious objection on Sutton's theory.
- After some years the objection was cleared after the discovery of linkage by the historical experimentation of **T. H. Morgan** in 1910 on *Drosophila*.

Parallel behavior of genes and chromosomes during meiosis

Behavior of chromosomes	Behavior of genes
1- Diploid cells (before meiosis) have two copies of each chromosome (homologous pairs) while gametes (after meiosis) have only one. E.g. In pea plant diploid cells have 7 pairs of homologous chromosomes while gametes have single 7 chromosomes.	1- According to the Mendel, diploid cells have two copies of each gene (pair of alleles) while gametes have only one. e.g. In pea plant, diploid cells have pairs of alleles for each gene like Rr, Yy, and Tt, while gametes have single R or r, Y or y and T or t
2- Homologous pairs of chromosomes segregate during meiosis.	2- According to the Mendel, pair of gene for each trait also segregates from each other during meiosis. e.g. Rr
3- During meiosis, each pair of homologous chromosomes orients on the metaphase plate independently of any other pair so that in anaphase each pair assorts independently of the other.	3- According to Mendel, alleles of one gene pair also assort independently to the alleles of other gene pair during meiosis. e.g. RrYy genotype as a result of independent assortment can form four type of gametes i.eRY, Ry, rY, and ry.

CONCEPT OF GENE

- It is the basic unit of biological information.
- Genes are actually parts of DNA comprising its basic sequence.
- It is sequence of nucleotides that specifies the sequence of amino acids in a polypeptide chain.

Locus

- The position of a gene on the chromosome is called its locus.

Allele

- Genes form pairs on pairs of homologous chromosomes.

- One member of a gene pair is located on one homologue and the other member on the other homologue.
- Partners of a gene pair are called alleles.
- Each allele of a gene pair occupies the same gene locus on its respective homologue.
- Both alleles on one locus may be identical or different from each other.

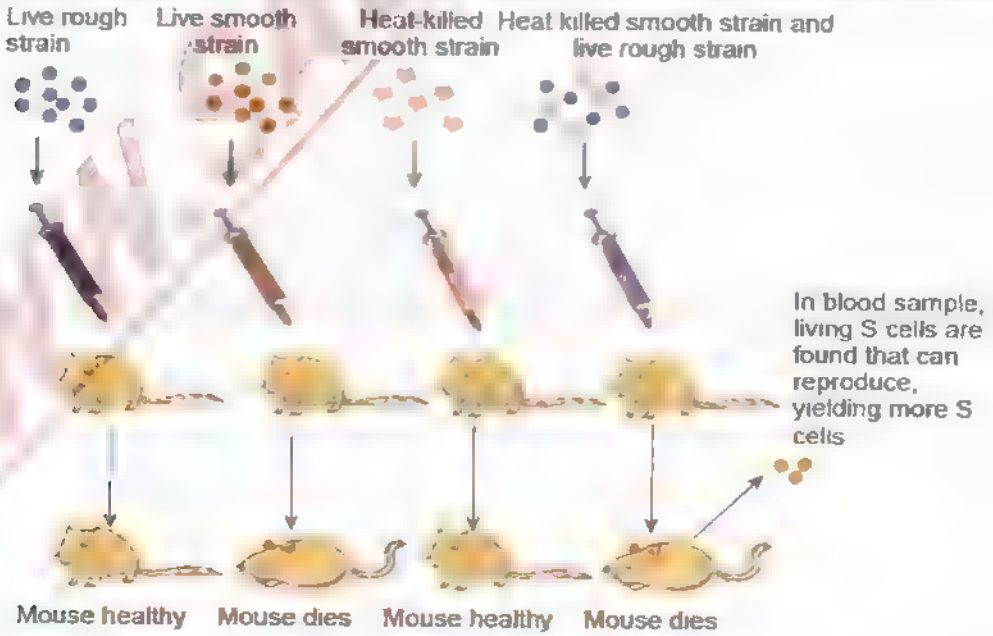
Work of Frederick Griffith

- Frederick Griffith was a British microbiologist who provided first evidence about hereditary nature of DNA.
- He used *Streptococcus pneumoniae* bacteria. There are two types of *S. pneumoniae*;
- S-form is virulent and contains polysaccharide coat necessary for virulence.
- R-form is non-virulent. It lacks an enzyme needed to manufacture polysaccharide coat. He performed following experiments.
- When he infected mice with virulent strain of *S. pneumonae* S-form, it died of blood poisoning.
- When he infected similar mice with mutant strain of *S. pneumonae* that lacked the virulent strains polysaccharides coat R form, it did not cause the death.
- He injected dead bacteria of S-virulent strain into the mice, the mice remained perfectly healthy.
- As a control, he injected mice with a mixture containing dead S bacteria of virulent strain and live coatless R bacteria although each of them did not harm mice separated but their mixture caused death of mice. In blood of dead mice live S bacteria were found.

Transformation

"It is the transfer of genetic material from one cell to another altering genetic makeup of the recipient cell."

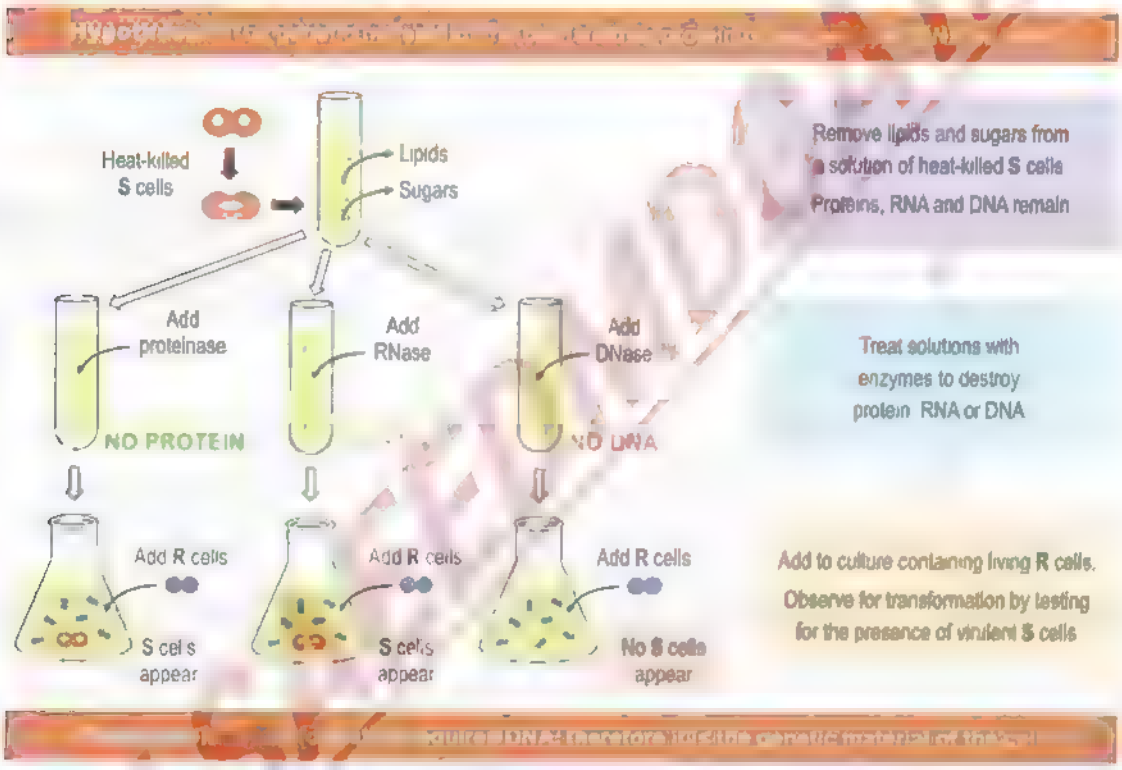
From these experiments he concluded that some information specifying the polysaccharide coat had passed from the dead, virulent S bacteria to the live, coatless R bacteria in the mixture, permanently transforming the coatless R bacteria into the virulent S variety



Work of Avery, Macleod and McCarty

They discovered agent responsible for transforming streptococcus. They performed following experiments.

- They prepared mixture of dead S streptococcus and live R streptococcus and removed much of the protein (99.98%) by applying protein digesting enzyme.
  Transforming activity was not reduced.
- They removed much of RNA by applying RNA digesting enzyme.
  Transforming activity was still present.
- They removed DNA by applying DNAase. At that time transforming activity was lost.



Work of Hershey and Chase

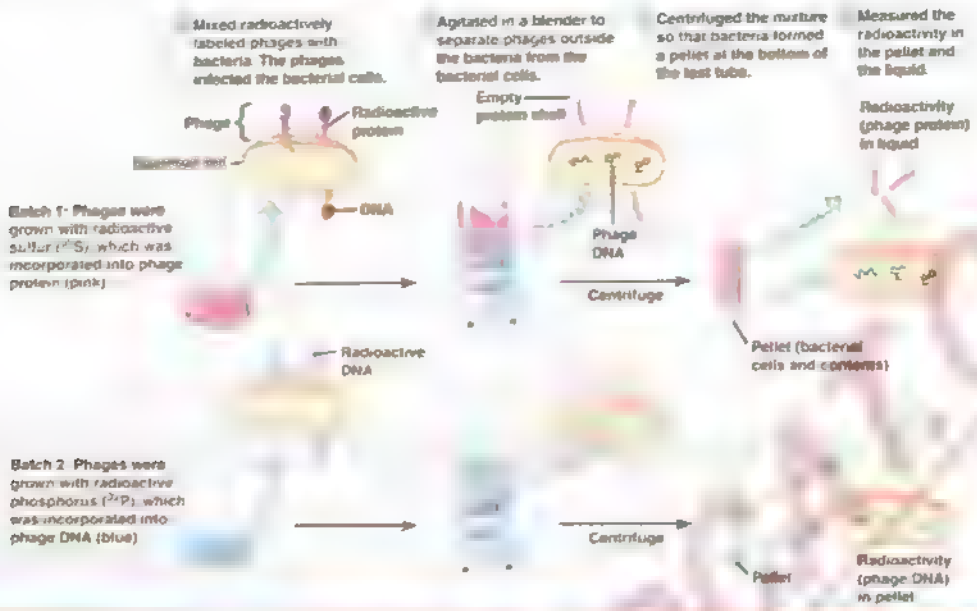
They performed experiment with bacteriophages (T_2) supporting Avery's conclusion.

(i) In an experiment, they labeled viruses with radioisotope ^{32}P being incorporated into newly synthesized DNA of growing phage.

(ii) In other experiment, they labeled viruses with radioisotope ^{35}S being incorporated into the amino acids of newly synthesized protein coats.

After labeled viruses were permitted to infect bacteria, bacterial cells were agitated violently in a blender to remove the protein coats of the infecting viruses from the surface of bacteria. This procedure removes nearly the entire ^{35}S label from the bacteria.

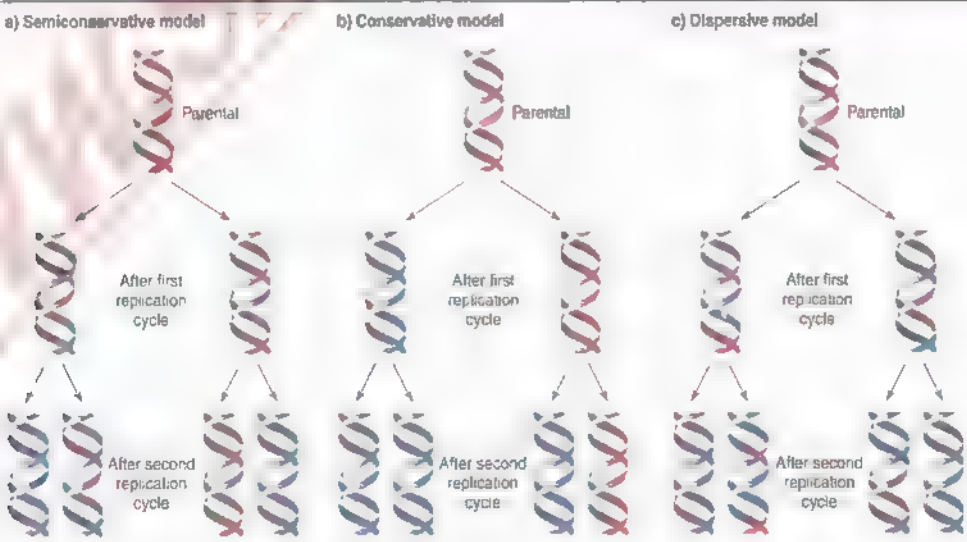
However, ^{32}P label had transferred to the interior of the bacteria and was found in viruses subsequently released for the infected bacteria. Hence the hereditary information injected into the bacteria that specified the new generation of viruses was DNA and not protein.



MODELS OF DNA REPLICATION

- Semi-conservative replication model was presented by Watson and Crick.
- Semi-conservative replication was confirmed by **Meselson and Stahl.**
- In **semi-conservative replication,** the sequence of the original duplex is conserved after one round of replication, the duplex itself is not.
- According to **conservative model,** parental double helix would remain intact and generate DNA copies consisting of entirely new molecules.
- According to **dispersive model,** parental DNA would become completely dispersed and each strand of all daughter molecules would be a mixture of old and new DNA molecules.

Model	Primary Structure	Secondary Structure
Conservative Model	Conserved	Conserved
Dispersive Model	Lost	Lost
Semi-conservative Model	Conserved	Lost



MESELSON AND STAHL EXPERIMENT

- The three hypothesis of DNA replication were evaluated by M. Meselson and F. Stahl.
- They grew bacteria in a medium containing heavy isotopes of nitrogen N^{15}, which became incorporated into the bases of the bacterial DNA.

Step I

Growth of Bacteria in Artificial Medium

- They grew bacteria in a medium containing **heavy isotope of nitrogen(N^{15})**, which became incorporated into the bases of the bacterial DNA. After several generations, the DNA of these bacteria was denser than that of bacteria grown in a medium containing the lighter isotope of nitrogen (N^{14}).
- Then they transferred the bacteria from the N^{15} medium to the N^{14} medium and collected the DNA at various intervals.

Step II

Ultracentrifugation

- They dissolved the DNA in **cesium chloride** and then spun it at a very high speed in an ultracentrifuge. DNA strands of different densities got separated.
- Each DNA floats or sinks in the gradient until it reaches the position where its density exactly matches the density of cesium chloride there.
- Because N^{15} strands are denser than N^{14} strands, they migrate farther down the tubes to a denser region of the cesium chloride gradient.

Observations

- The DNA collected immediately after the transfer was all dense.
- After the bacteria completed their first round of DNA replication in the N^{14} medium, the density of their DNA had decreased to a value intermediate between N^{14}-DNA and N^{15}-DNA.
- After the second round of replication, two density classes of DNA were observed, one intermediate and one equal to that of N^{14}-DNA.

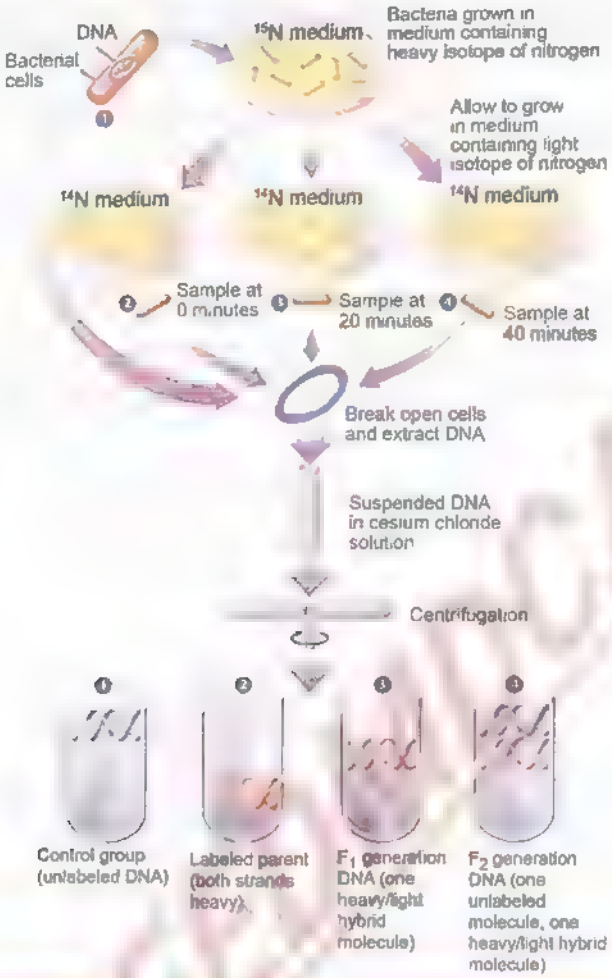
Interpretations

Meselson and Stahl interpreted their results as follows:

- After the first round of replication, each daughter DNA duplex was a hybrid possessing one of the heavy strand of parent molecule and one light strand.
- When this hybrid duplex replicated, it contributed one heavy strand to form another hybrid duplex and one light strand to form a light duplex.

Conclusion

This experiment clearly confirms the prediction of Watson - Crick Model that DNA replicates in a semi-conservative manner.



PROCESS OF DNA REPLICATION

- The DNA replication begins at one or more sites on the DNA molecule, where there is specific sequence of nucleotides. This sequence is called **origin of replication.**
- The DNA polymerase III and other enzymes begin a complex process that catalyzes the addition of nucleotides to the growing complementary strands of DNA.

Enzymes/ Proteins Involved

(i) Helicase

- It opens the double helix of DNA by breaking hydrogen bonds.

(ii) SSBPs

- Single stranded binding proteins prevent recoiling of DNA.

(iii) Primase

- Primase constructs an RNA primer, a sequence of about 10 RNA nucleotides complementary to the parent DNA template.

(iv) DNA Polymerases

- DNA polymerases catalyze addition of nucleotides to the complementary growing strands of DNA.
- They are of three types I, II and III in bacteria.
- The true *E. coli* replicating enzyme is DNA polymerase III which is **10 times larger**.
- This enzyme is a dimer and catalyzes replication of one DNA strand.

- **Rate of replication** is 1000 nucleotides/sec.
- It can add nucleotides only to a chain of nucleotides that is already paired with the parent strands.
- DNA polymerase **cannot initiate synthesis** on its own.
- It can add nucleotides to the 3' end of a DNA strand so replication always proceeds from **5'→ 3'**direction on a growing DNA strand.

(v) DNA Ligase

- It connects DNA fragments together.

Mechanism

Following steps are involved during DNA replication:

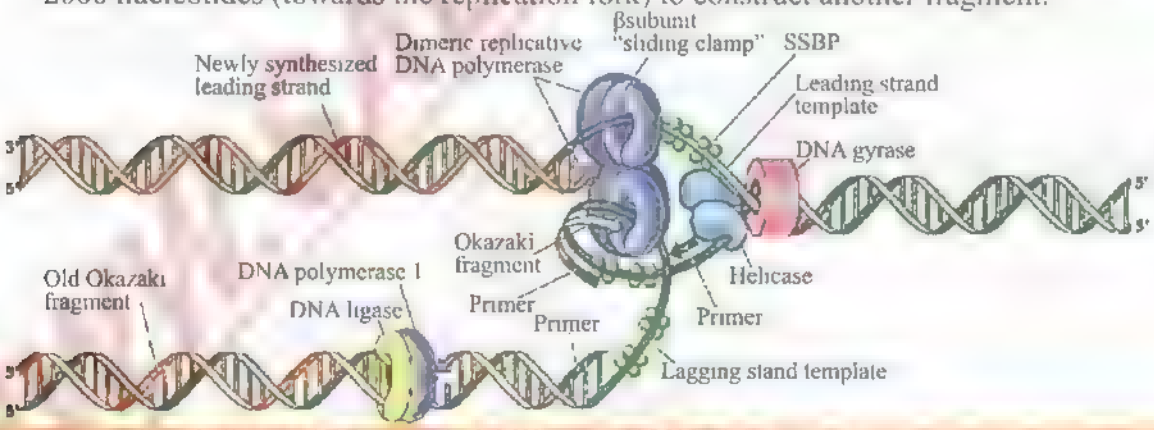
(i) Helicase opens double helix of DNA and SSBPs prevent recoiling.

(ii) Primase adds primer complementary to DNA strand.

(iii) DNA polymerase III recognizes primer and constructs new strand in 5' → 3'.

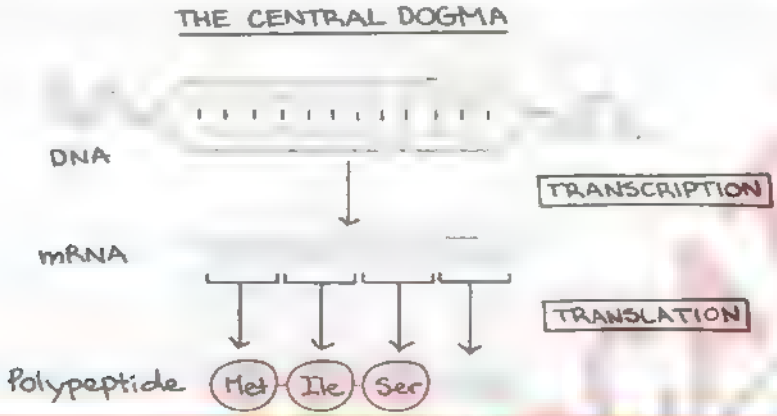
(iv) **Leading strand,** which elongates towards the replication fork, is built up simply by adding nucleotides continuously to its growing 3' end.

- **Lagging strand,** which elongates away from replication fork, is synthesized discontinuously as a series of short segments that are later connected.
- These segments called **Okazaki fragments** are 100-200 nucleotides long in eukaryotes and 1000-2000 nucleotides long in prokaryotes Each segment is synthesized in 5' → 3', beginning at the replication fork and moving away from it.
- When the polymerase reaches the 5' end of the lagging strand, **DNA ligase** connects these Okazaki fragments.
- The DNA is further unwound, new RNA primers are constructed and DNA polymerase III then jumps ahead 1000-2000 nucleotides (towards the replication fork) to construct another fragment.



- **Central dogma** is the basic mechanism of reading and expressing genes in living organisms.
- The genetic information resides in DNA and flows down into RNA, which is then translated into proteins.
- The first step of central dogma is the transfer of information from DNA to RNA, which occurs when an mRNA copy of a gene is produced. The process is called **transcription**. mRNA synthesized is complementary transcript of the copied gene.

- The second step of central dogma is the transfer of information from RNA to proteins, which occurs when the information contained in the mRNA is used to direct the synthesis of polypeptides by ribosomes. The process is called **translation** because sequence of nucleotides in mRNA is translated into amino acid sequence of polypeptide.



TRANSCRIPTION

Transcription is the process by which an RNA copy of the DNA sequence encoding the gene is produced with the help of an enzyme, **RNA polymerase.**

Role of RNA Polymerase

- RNA polymerase enzyme synthesizes RNA from 5′ to 3′.
- There is only **one type of RNA polymerase in prokaryotes** which is responsible for the synthesis of all three types of RNAs.
- In eukaryotes, **RNA polymerase I** synthesizes rRNA, **RNA polymerase II** mRNA and **RNA polymerase III** synthesizes tRNA.

Mechanism of Transcription

(i) Binding

- Transcription starts from promoter on DNA template strand.
- The binding of RNA polymerase to the promotor is the first step in gene transcription.
- Promotor is located **upstream of gene.**
- Two binding sites in prokaryotes and eukaryotes are:

Promotor Site	Prokaryotes	Eukaryotes
TTGACA	-35	-75
TATAAT	-10	-25

(ii) Initiation

- One of the subunit of RNA polymerase is called **'sigma factor'**, which is responsible for correct initiation of transcription process.
- Once the transcription has started, the sigma factor is released and the remaining part of the enzyme (core enzyme) moves on the template strand and completes the transcription of the gene.

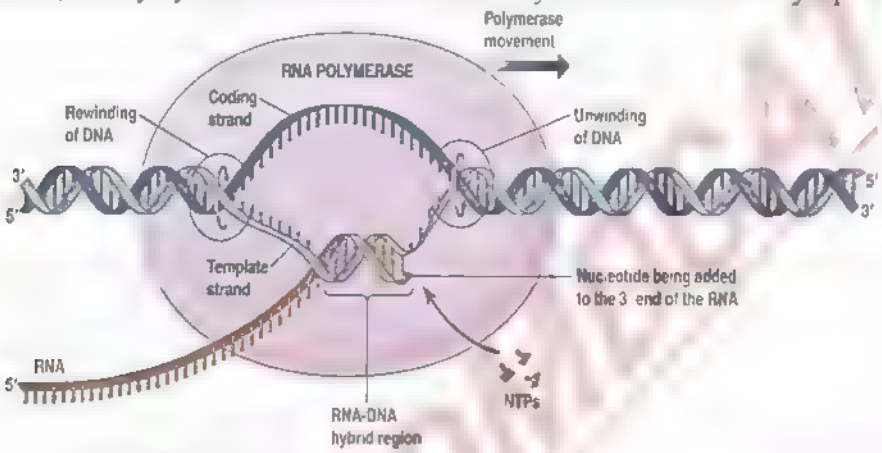
(iii) Elongation

- The DNA strands open up at the place where enzyme is attached to the template strand forming **transcription bubble**.
- RNA polymerase transcribes only one strand of DNA, which is called **template, or antisense strand or non-coding strand**.
- Other strand is called **coding strand or sense strand or opposite strand**.

- The transcription bubble moves down the DNA molecule, leaving the growing strand protruding from the bubble.

(iv) Termination

- The stop sequences at the end of gene terminate the synthesis of mRNA.
- The simplest stop signal is a **series of GC base pairs followed by a series of AT base pairs.**
- The RNA formed in this region forms a GC hairpin followed by four or more uracil ribonucleotides.
- The hairpin causes RNA polymerase to stop synthesis of RNA.
- In **bacteria,** newly synthesized mRNA is directly released into the cytoplasm.

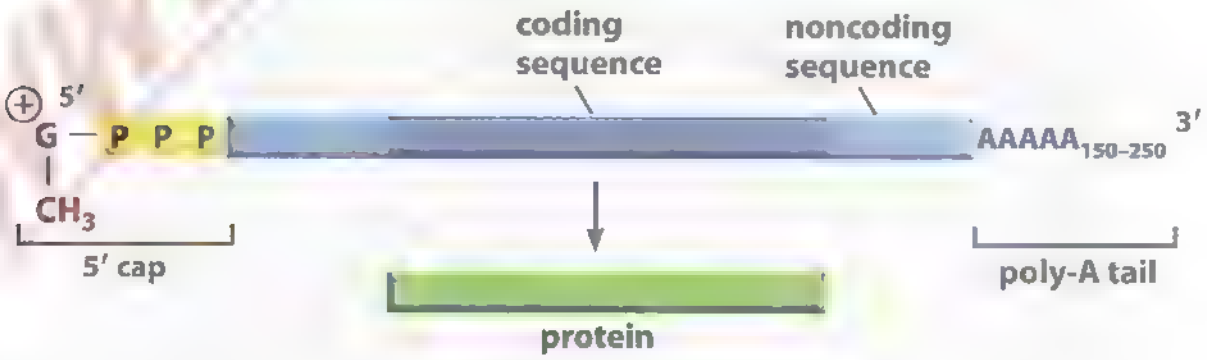


Post-Transcriptional Modifications

- In **eukaryotes,** mRNA has to travel a large distance from inside the nucleus to ribosomes outside in cytoplasm.
- In eukaryotes, mRNA is protected from action of **nucleases and phosphatase by addition of 7-methyl GTP,** linked 5′ to 5′ with first nucleotide. This is called 5'-capping.

- While at the 3'-end of mRNA, the poly 'A' tail linked to 3'. This is called 3'-end polyadenylation.

RNA capping and polyadenylation



- **Genetic code** is a combination of three nucleotides, which specify a particular amino acid in a polypeptide chain or a protein molecule.
- As there are three nucleotides in a codon so it is also called as triplet code.
- Triplet code present on mRNA is called codon while on tRNA is called anti-codon.

Codons

- There are total 64 codons for 20 amino acids.
- **Marshal Nirenberg, Philip Leader and Har Gobind Khorana** tested all 64 codons by making artificial mRNAs and triplet codons and using them to synthesize protein or aminoacyl-tRNA complexes in cell free system.
- Out of 64 codons, 3 codons UAA, UAG and UGA do not code for any amino acid and so known as **nonsense codon** or **stop codon.**
- Every gene starts with initiation codon AUG, which encodes the amino acid methionine. This is called **start codon.**

Genetic Code – Universal or Non-Universal

- The genetic code is universal. It is same in almost all the organisms.
- For example, AGA specifies arginine in bacteria, in humans and all other organisms.
- Because of universality of codon, the gene can be transferred from one organism to another.
- The study of genetic code of mitochondrial DNA, however, showed that genetic code is not that universal.
- Following are few examples:

Codon		
UGA	Stop codon	Tryptophan
AUA	Isoleucine	Methionine
AGA, AGG	Arginine	Stop codon

UUU, UUC: Phenyl alanine UUA, UUG: leucine	UCU, UCC, UCA, UCG: serine	UAU, UAC: tyrosine UAA, UAG: stop	UGU, UGC: cysteine UGA: stop UGG: tryptophan
CUU, CUC, CUA, CUG: leucine	CCU, CCC, CCA, CCG: proline	CAU, CAC: histidine CAA, CAG: glutamine	CGU, CGC, CGA, CGG: arginine
AUU, AUC, AUA: isoleucine AUG: methionine	ACU, ACC, ACA, ACG: threonine	AAU, AAC: asparagine AAA, AAG: lysine	AGU, AGC: serine AGA, AGG: arginine
GUU, GUC, GUA, GUG: valine	GCU, GCC, GCA, GCG: alanine	GAU, GAC: aspartic acid GAA, GAG: glutamic acid	GGU, GGC, GGA, GGG: glycine

TRANSLATION

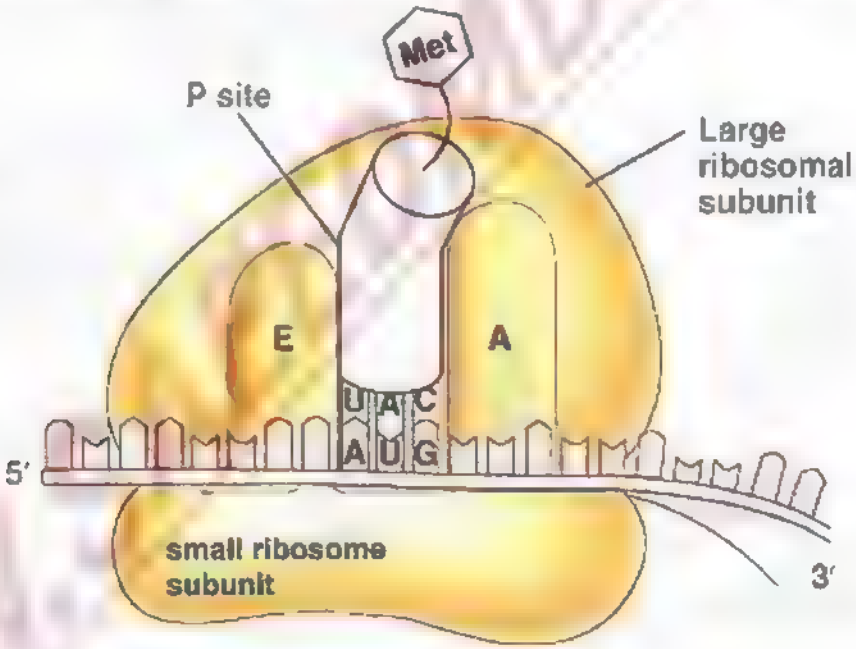
- It is the process by which amino acids are arranged in form of polypeptide chain according to the sequence of nucleotides in mRNA.

Formation of Aminoacyl-tRNA

- Particular tRNA molecules become attached to specific amino acids through the action of activating enzymes called **aminoacyl-tRNA synthetase.**
- For 20 different amino acids, there are 20 different tRNA and enzymes.

(i) Initiation

- In prokaryotes, polypeptide synthesis begins with the formation of **initiation complex**.
- First a tRNA molecule carrying a chemically modified methionine (called N-formyl methionine) binds to the smaller ribosomal subunit. This is done by **initiation factor.**
- Initiation factor position the tRNA on the ribosomal surface at the **'P site'** (peptidyl site) where peptide bonds will form. Nearby two other sites will form.
- **'A site'** (aminoacyl site) where successive aminoacyl-tRNA will bind.
- **'E site'** (exit site) where empty tRNA will exit the ribosome.
- This initiation complex, guided by another initiation factor, binds to AUG on the mRNA.



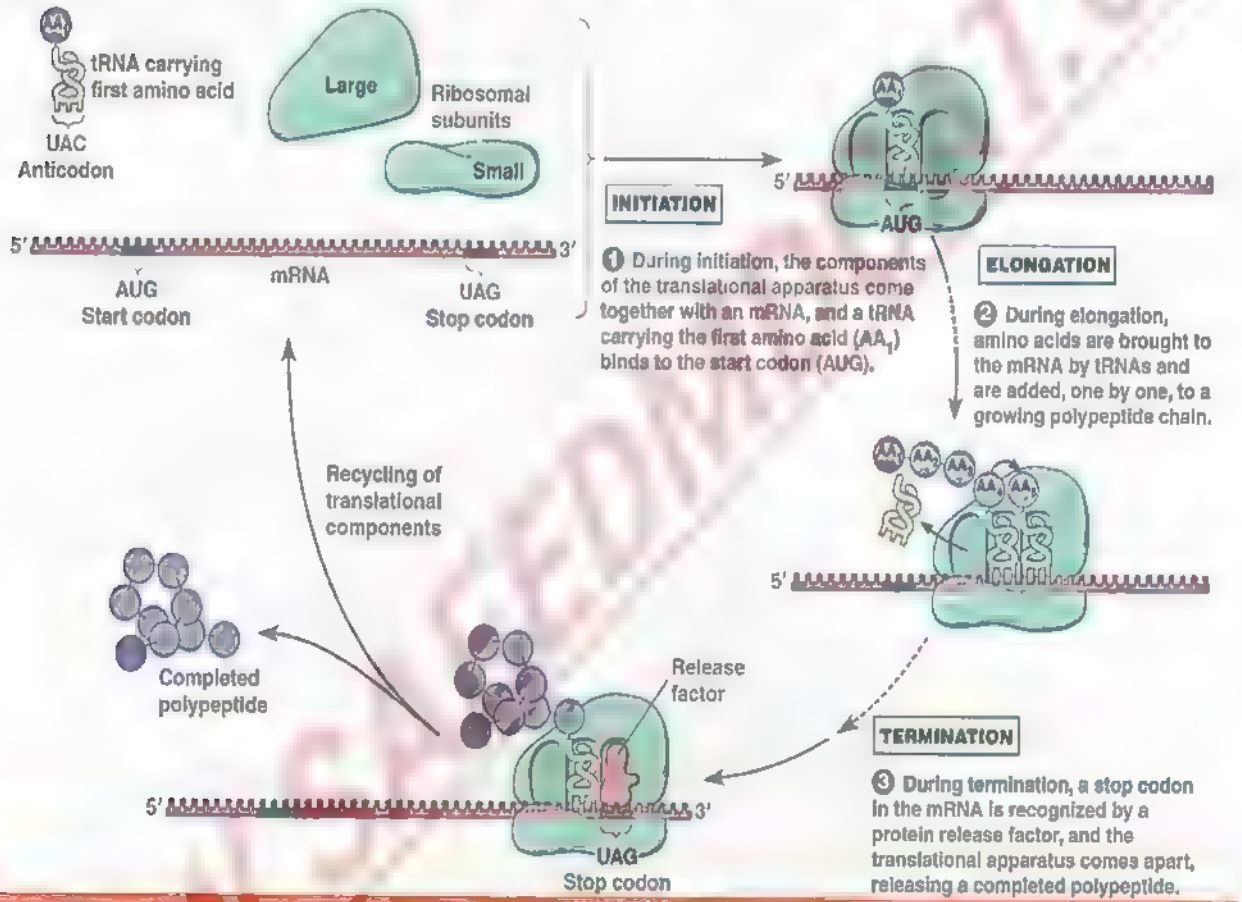
(ii) Elongation/Translocation

- Larger ribosomal subunit binds with small subunit on mRNA.
- An elongation factor binds another aminoacyl-tRNA at 'A site'.
- The two amino acids which now lie adjacent to each other undergo a chemical reaction, **catalyzed by the large ribosomal subunit**, which releases the initial methionine from its tRNA and attached it by a peptide bond to the second amino acid.
- The ribosome now moves (translocate) three more nucleotides along the mRNA molecule in the 5' → 3' direction, guided by another elongation factor.

- This movement translocates the initial tRNA to the 'E site' and ejects it from the ribosome and repositions the growing polypeptide.
- Same process is repeated again and again.

(iii) Termination

- Elongation continues in this fashion until a chain-terminating non-sense codon is exposed (e.g. UAA).
- Nonsense codons do not bind to tRNA but they are recognized by release factors that release the newly made polypeptide from the ribosomes.



MUTATION

- A gene mutation is a permanent change in the DNA sequence that makes up a new allele in the population.
- Mutations range in size from change in a single DNA nucleotide to a large segment of a chromosome or whole chromosome or sometimes changes in the number of chromosome.
- The agents that causes mutations are called mutagens while the organism or cell in which mutation is occurred is called **mutant**.

Mutagens

Mutagens are chemical compounds or radiation (such as UV or X-rays) that causes irreversible and heritable changes (mutations) in the cellular genetic material DNA. The sources of mutation may be physical, chemical and biological agents.

Physical Mutagens

Physical mutagens include radiation of any kind i.e., UV, gamma rays, X-ray, radioactive, high temperature alterations.

Chemical Mutagens

The chemical mutagens include colchicines, mustard gas, nitrous gas, acridine orange, reactive radioactive isotopes, and free oxygen particles etc.

Biological Mutagens

Biological mutagens may include certain viruses, transposons and errors that occur during meiosis or DNA replication.

Types of Mutations

Generally, there are two types of mutations e.g. chromosomal and point mutation.

Chromosomal Mutations

"Changes in structure or number of chromosomes are referred as chromosomal mutations or chromosomal aberrations."

Down syndrome

Down syndrome is characterized by 2n+1 as these persons have an extra copy of 21st chromosome (trisomy 21).

Klinefelter's Syndrome

It is characterized by 2n+1 (44+XXY).

Turner syndrome

It is characterized by 2n-1 (44+XO). The affected individuals are females.

Gene/Point Mutations

- A gene or point mutation arises as a result of a chemical change in an individual gene.
- An alternation in the sequence of nucleotides in the part of a molecule that corresponds to a particular gene changes the order of amino acids making up a protein.
- These may include base substitution (replacement of one base by another), insertion (addition of one or more bases) and deletion (removal of one or more bases).
- Frame shift mutations occur when one or more nucleotides are either inserted or deleted from DNA. This results in the completely new sequence of codons and a non-functional protein.

Sickle Cell Anemia

The sickle cell anemia is also known as Hemoglobin SS disease (Hb SS); Sickle cell disease.

Phenylketonuria

A rare condition in which a baby is born without the ability to properly break down an amino acid called phenylalanine is called phenylketonuria.

TOPIC-17 EVOLUTION

- Concept of Evolution
- Evolution of Eukaryotes from Prokaryotes
- Lamarckism
- Darwinism
- Evidences of Evolution

In the earlier 19th century, there were two schools of thoughts.

- Creationists believed on theory of **special creation.**
- Evolutionists believed on theory of **natural selection.**

(i) Theory of Special Creation

According to this theory, all living things came into existence in their present forms especially and specifically created by nature. Among the scientists who believed in divine creation was C. Linnaeus. C. Linnaeus in the eighteenth-century classified organisms. He grouped similar species in the same genus and similar genera in one family. But as a natural theologian, he believed that species were permanent creations. C. Linnaeus was one of the believers of this theory.

(ii) Theory of Natural Selection

According to this theory, organisms evolved through time, with one type of organism giving rise to another type of organism.

It is ancient one starting from days of Aristotle to Darwin.

However, the present-day concept of evolution is based on history.

Scientist's Name	Life Span	Achievements
Linnaeus	1707-1778	Order in diversity of life, binomial nomenclature
Lamarck	1744-1829	Theory of evolution
Malthus	1766-1834	Essay on 'Principle of Population'.
Cuvier	1769-1832	Science of Palaeontology, earth's history by catastrophism.
Lyell	1797-1875	Principles of Geology
Darwin	1809-1882	1. Voyage of Beagle. 2. Books on origin of species. 3. Essay on origin of species.
Mendel	1822-1884	Papers on inheritance
Wallace	1823-1913	Sent his theory to Darwin

Different speculations about the origin of first life form and evolution of prokaryotes into eukaryotes are mentioned briefly.

Hydrothermal Vent Hypothesis

Origin of First Life Form

- According to one concept, life may have originated in the oceans, in underwater hot springs called hydrothermal vents. These vents could have supplied the energy and raw materials for the origin and survival of early life forms.

- Archaebacteria are considered as first life form, which support this vent hypothesis because they can tolerate temperature up to 120°C and undergone less evolutionary changes than any other living species.
- As bacteria are prokaryotes, so prokaryotes are considered as first life form on earth.

Evolution of Photosynthetic Organisms

- Nutrients produced in primitive environment would have limited early life. Photosynthesis, another source of nutrients, probably freed living organisms from a dwindling supply of nutrients.
- First photosynthetic organisms probably used hydrogen sulfide as a source of hydrogen for reducing carbon dioxide to sugars.
- Later water served this same purpose and oxygen liberated by photosynthetic reaction begun to accumulate in the atmosphere.

Evolution of Aerobic Respiration

- Accumulation of oxygen in atmosphere changed the primitive environment.
- Ozone developed by oxygen in upper atmosphere began to filter ultraviolet radiations from the sun It is considered that about 4.2 billion (420 million) years ago, enough protective ozone had built up to make life on land possible.
- Reducing atmosphere slowly changed into oxidizing atmosphere.
- Some living organisms began to utilize oxygen.
- Ironically, the change from a reducing atmosphere to an oxidizing atmosphere also means that life could no longer arise abiotically.

Evolution of Prokaryotes into Eukaryotes

- The prokaryotes may have arisen more than 3.5 billion years ago.
- Eukaryotes may have evolved 1.5 billion years ago.

It is considered that prokaryotes converted into eukaryotes. Major change is development of organelles. Two hypotheses are considered in this context.

Endosymbiont Hypothesis

This hypothesis was presented by Lynn Margulis.

According to this hypothesis, eukaryotes and their organelles had been produced by some symbiotic relation with prokaryotes. Origin of some organelles has been described below.

(i) **Origin of Mitochondria**

According to this hypothesis eukaryote cell might have evolved when large anaerobic amoeboid prokaryote ingested small aerobic bacteria and stabilized them instead of digesting them. This idea is known as the endosymbiont hypothesis.

These aerobic bacteria then converted into mitochondria, which are the sites of aerobic respiration and energy conversion in eukaryotic cells.

(ii) **Origin of Flagella**

Flagella (whip-like structure) might have evolved through the ingestion of prokaryotes similar to spiral-shaped bacteria (spirochetes).

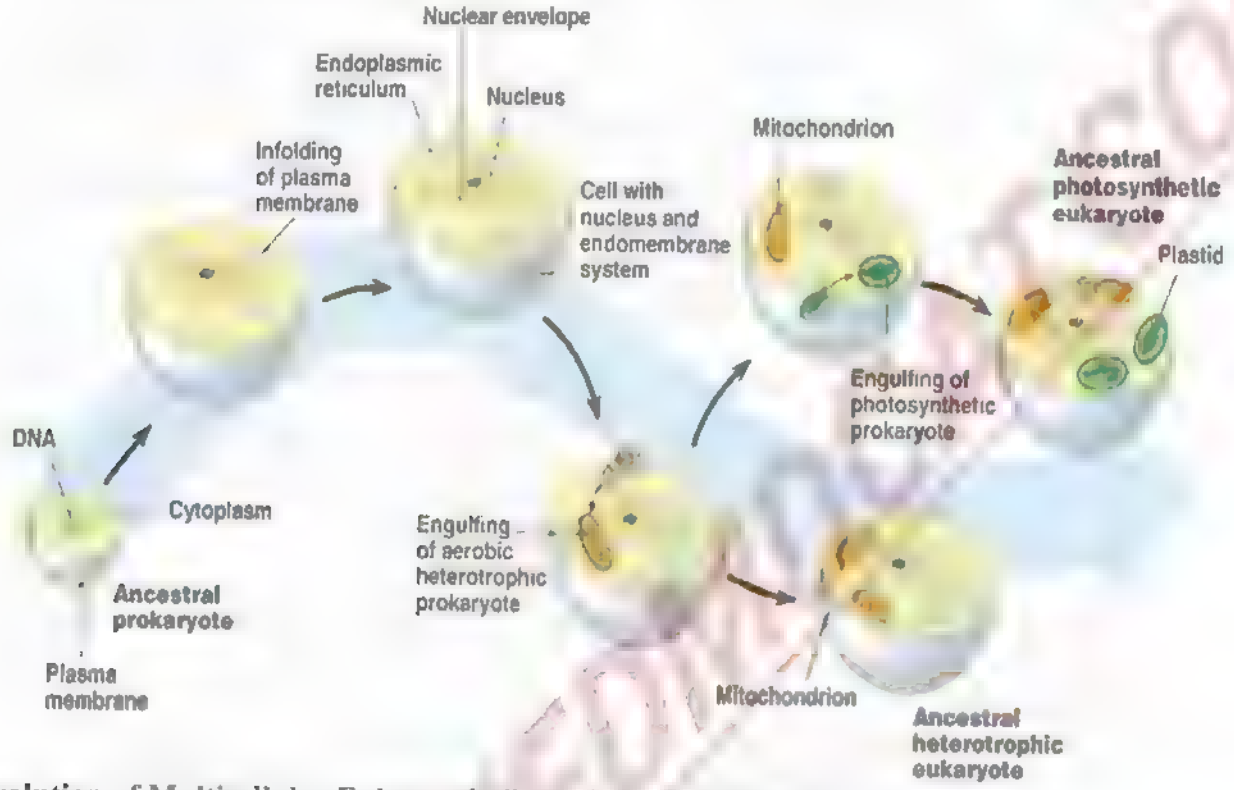
(iii) **Origin of Chloroplast**

Ingestion of prokaryotes that resembled present day cyanobacteria could have led to the endosymbiotic development of chloroplast in plants.

Cell Membrane Invagination Hypothesis

According to this hypothesis, cell membrane of prokaryotes invaginates (folded inward) to enclose copies of its genetic material.

This invagination resulted in the formation of several double membrane-bounded entities (organelles) in single cell. These entities could then have evolved into the eukaryotic mitochondrion, nucleus, chloroplast etc.



Evolution of Multicellular Eukaryotic Organism and Diversity

- Formation of eukaryotic cell led to a dramatic increase in the complexity and diversity of life forms on earth.
- During evolution, eukaryotic cell became specialized into tissues, which in turn formed organs for many different functions. These multicellular forms then adapted themselves to life in a great variety of environment.

Lamarckism

Lamarck's Theory

- **Jean Baptiste Lamarck** (1744-1829) published his theory of evolution in 1809, the year Darwin was born.
- Two important points of **Lamarck's theory** are; use and disuse of organs and inheritance of acquired characters.

Use and Disuse of Organs

- Lamarck argued that those parts of the body used extensively to cope with the environment become larger and stronger e.g. blacksmith developing a bigger biceps in the arm that works the hammer. Similarly, giraffe stretching its neck to new lengths in pursuit of leaves to eat.

- Those parts that are not used deteriorate e.g. loss of legs in snakes due to their habitat of burrows and bushes.

Inheritance of Acquired Characters

- According to Lamarck, inheritance of acquired characters means that the modifications an organism acquires during its lifetime can be passed along to its offspring e.g. the long neck of giraffe, Lamarck reasoned, evolved gradually as the cumulative product of a great many generations of ancestors stretching higher and higher.

Demerits of Lamarck's Theory

It has been now known that acquired characters cannot be inherited.

DARWINISM

- Darwin observed and collected thousands of specimens of diverse faunas and floras of South America.
- His main observations were about fauna and flora of Galapagos Islands where he collected 13 types of finches.
- **According to Darwin,** new species would arise from an ancestral form by the gradual accumulation of adaptations to different environments, separated from original habitat by geographical barriers. Over many generations, the two populations could become dissimilar enough to be designated as **separate species**.
- In 1844 Darwin wrote a long essay on the origin of species and natural selection, his book **the origin of species** was published in 1859.

Descent with Modification

- Darwin believed in **perceived unity in life** i.e all organisms related through descent from some common ancestor that lived in the remote past.
- According to Darwin, history of life is like a tree, with multiple branching and re-branching from a common trunk all the way to the tips of the living twigs, symbolic of the current diversity of organisms.

Natural Selection and Adaptation

- Darwin suggested that populations of individual species become better adapted to their local environments through natural selection.
- Darwin's theory of natural selection was based on the following observations:

(i) Overproduction

Production of more individuals than the environment can support.

(ii) Struggle for Existence

Struggle for existence among individuals of a population, with only a fraction of offsprings surviving each generation.

(iii) Survival of the Fittest

It means survival in the struggle for existence is not random but depends in part on the heredity constitution of the surviving individuals. Those organisms whose inherited characteristics fit them best to their environment are likely to leave more offsprings than the less fit individuals.

(iv) Evolution

This unequal ability of individuals to survive and reproduce will lead to a gradual change in a population, with favorable characteristics accumulating over the generations thus leading to the evolution of new species.

Neo-Darwinism

- Since natural selection was proposed, advances in genetics, biochemistry, ecology and paleontology have enabled scientists to identify mutation, genetic drift and gene flow as other natural forces of evolutionary change.
- The pioneering work of Cheverikov, Mayr, Simpson and many others led to what become known as the modern synthesis.
- **Neo-Darwinism**, which emphasizes the **role of genetics** in explaining how evolution works. The modern theory accepts five major causes of evolution.

Biogeography

- It is the geographical distribution of species.
- It was first evidence that suggested idea of evolution to Darwin.
- According to Darwin, islands have many species of plants and animals that are endemic but closely related to species of the nearest mainland or neighboring island.
- Armadillos (armored mammals) live only in America. The evolutionary view of biogeography predicts that contemporary armadillos are modified descendants of earlier species that occupied these continents and fossil records also confirm existence of such ancestors.

Paleontology

- The succession of fossil forms is a strong evidence in favour of evolution.
- It provides a visual record in a complete series showing the evolution of an organism.
- **Fossils** are either the actual remains or traces of organisms that lived in ancient geological times.
- Most fossils are found in **sedimentary rocks.**
- The oldest known fossils are of prokaryotes.
- They show chronological appearance of the different classes of vertebrate animals as shown by fossils. It shows following evolutionary arrangement:
- Fishes → Amphibians → Reptiles → Mammals + Birds

Comparative Anatomy

- Anatomical similarities between species grouped in the same taxonomic category bring another support to the theory of the Descent with modification.
- Comparative anatomy supports that evolution is a remodeling process in which ancestral structures that functioned in one capacity become modified as they take on new functions.

Homologous Structures

- Such organs, which are functionally different but structurally similar are called homologous organs.
- Similarity in characteristics resulting from common ancestry is known as **homology** and such anatomical signs of evolution are called homologous structures.
- For examples, same skeletal elements make up the forelimbs of human, cats, whales, bats and all other mammals although they have different functions.
- The basic similarity of these forelimbs is the consequence of the descent of all functions.
- The flower parts of a flowering plant are homologous. They are considered to have evolved from leaves, to form sepals, petals, stamens and carpels.
- They are considered to be evolved by **divergent evolution.**

Analogous Structures

- Such organs, which are functionally alike but structurally different, are called analogous organs.
- They are considered to be evolved by **convergent evolution.**
- For example, wings of birds and insects are examples of convergent evolution.

Vestigial Structures

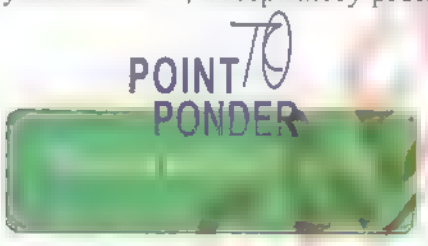
- Such organs, which are historical remnants of structures that had important functions in ancestors but are no longer essential presently, are called vestigial organs.
- These are oldest homologous structures.
- For example, skeleton of whales and some snakes retain vestiges of the pelvis and leg bones of walking ancestors, vermiform appendix in carnivores, ear muscles in man etc.

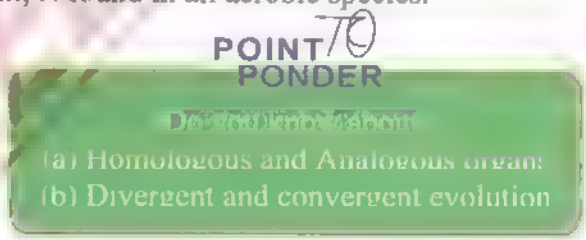
Molecular Biology

- The study of biochemical structures and functions of organisms at molecular level is called molecular biology.
- Evolutionary relationships among species are reflected in their **DNA and proteins**, in their genes and gene products. If two species have genes and proteins with sequences of monomers that match closely, the sequences must have been copied from a common ancestor.
- Molecular biology provides strong evidence in support of evolution as the basis for the unity and diversity of life.

Examples

- A common genetic code brings evidence that all life is related.
- Humans and bacteria have some common proteins.
- Cytochrome 'c', a respiratory protein, is found in all aerobic species.





TOPIC-18 BIOTECHNOLOGY

COVERAGE

- Recombinant DNA Technology
- Polymerase Chain Reaction
- Genomic Library
- DNA Sequencing
- DNA Analysis
- Transgenic Organisms
- Tissue Culture
- Biotechnology and Healthcare (Gene Therapy)

RECOMBINANT DNA TECHNOLOGY

Recombinant DNA

- **Recombinant DNA** contains DNA from two different sources.
- It is also called as chimeric DNA.
- Recombinant DNA technology is popularly known as genetic engineering.

Requirements of Recombinant DNA Technology

Four requirements of recombinant DNA technology are:

(i) Gene of interest which is to be cloned
(ii) Molecular scissors to cut out gene of interest
(iii) Molecular carrier or vector
(iv) Expression system

Gene of Interest

- Genes can be isolated from the chromosomes by cutting on flanking sites of the gene using special enzymes known as **restriction endonucleases**.
- If genes are small, these can also be synthesized in laboratory.
- Gene can be synthesized in the lab from mRNA using **reverse transcriptase.** Such DNA molecule produced from mRNA is called **complementary DNA (cDNA).**

Molecular Scissors: Restriction Endonucleases

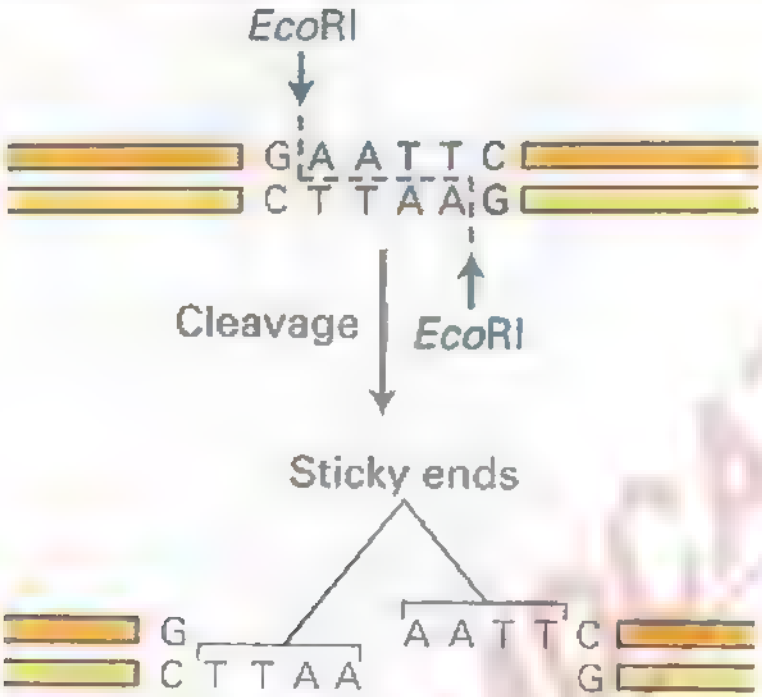
- These are the natural enzymes of bacteria, which they use for their own protection against viruses.
- The restriction enzyme cuts down the viral DNA but does not harm to bacterial chromosome. Thus, they restrict viral growth.
- First **restriction enzyme** was isolated by Hamilton O. Smith in 1970
- **400** restriction enzymes are discovered, **20** are commonly used.
- **Palindromic sequences** are sequences of four or six nucleotides arranged symmetrically in the reverse order produced by restriction enzymes, which cut the DNA at specific sites.
- **EcoR1** is a commonly used restriction enzyme.
- The single stranded but complementary ends of the two DNA molecules are called **sticky ends.**

POINT TO PONDER

Why restriction endonucl
not act on bacterial D

POINT TO PONDER

Can you differentiate b
endonuclease and exonuclease?

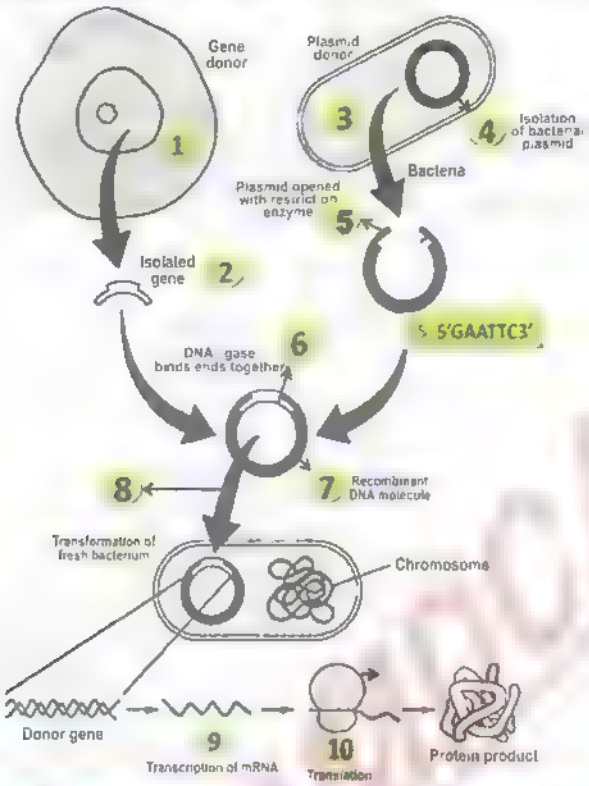


Molecular Carrier: Vector

- Vectors are the means by which recombinant DNA is introduced into a host cell.
- **Plasmids** are natural extra chromosomal circular DNA molecules which carry genes for antibiotic resistance and fertility. These were first discovered in intestinal bacterium Escherichia coli.
- **pSC 101** has antibiotic resistance gene for tetracycline.
- **pBR 322** has antibiotic resistance gene for tetracycline as well as ampicillin.
- **DNA ligase/molecular glue** are the enzyme which seals the foreign piece of DNA into the vector.

Expression of the Recombinant DNA

- Bacterial cells take up recombinant plasmid if they are treated with **calcium chloride** to make them more permeable.
- **Lambda phage** (DNA of bacterial viruses) can also be used as a vector.
- A clone can be a large number of molecules or cells or organisms that are identical to an original specimen.
- Bacterial cells after taking recombinant DNA are cloned. Each clone contains gene of interest which will express itself and make a product.
- From this bacterial clone, the cloned gene can be isolated for further analysis or protein product can be separated.



POLYMERASE CHAIN REACTION

- **Polymerase chain reaction** (PCR) was developed by Kary B. Mullis in 1983.
- **PCR** takes its name from DNA polymerase, the enzyme that carries out DNA replication process in cell.
- PCR is done in automatic PCR machine or thermocycler.
- PCR can create millions of copies of a single gene or any specific piece of DNA quickly in a test tube.
- PCR is very specific, the targeted DNA sequence can be less than one part in a million of the total DNA sample.

Main Requirements of PCR

- **Primers** are the sequences of about 20 bases that are complementary to the bases on either side of the target DNA. Primers are needed because DNA polymerase does not start the replication process; it only continues or extends the process.
- DNA polymerase used is **temperature–insensitive** (thermostable) enzyme extracted from the bacterium ***Thermus aquaticus***. This enzyme is also known as **Taq polymerase**.

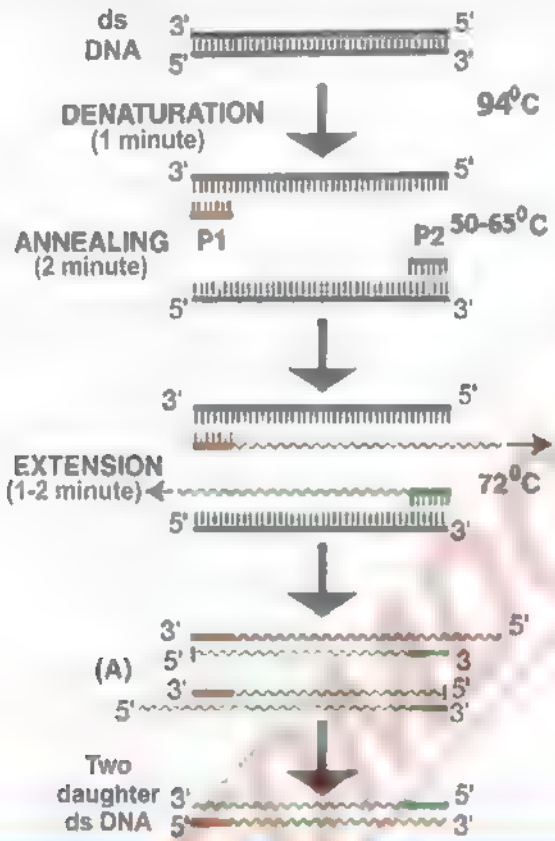
POINT TO PONDER

POINT TO PONDER

Can you differentiate between primer used in PCR and DNA replication?

POINT TO PONDER

Basic Mechanism



GENOMIC LIBRARY

- A **genomic library** is a collection of bacterial or bacteriophage clones, each clone containing a particular segment of DNA from the source cell. While a **genome** is a full set of genes of an individual.

Development of Genomic Library

- For making a genomic library, an organism's DNA is simply sliced up into pieces, and pieces are put into vectors (i.e. plasmids or viruses) that are taken up by host bacteria.
- The entire collection of bacterial or bacteriophage clones that results contains all the genes of that organism.

Searching a Gene in Library

- A particular **probe** can be used to search a genetic library for a certain gene. A probe is;
- A single stranded nucleotide sequence.
- Either radioactive or fluorescent.
- Hybridized (paired) with a certain piece of DNA.

Following steps are taken to search a particular gene in genomic library,

(i) Bacterial cells, each carrying a particular DNA fragment, can be plated onto agar in a Petri dish.

(ii) Probe is applied on it and it is hybridized with particular gene.

(iii) After the probe hybridizes with the gene of interest, it is identified due to radioactivity or fluorescence and is isolated from the fragment.

(iv) Now this particular fragment can be cloned further or even analyzed for its particular DNA sequence.

DNA SEQUENCING

It is a technique to find sequence of nucleotides in a gene.

Main Principles of Method

- Generation of different sized DNA fragments of all starting from the same point and ending at different points.
- Separation of these different pieces of DNA on agarose gel.
- Reading of sequence from the gel.

Methods to Generate Pieces of DNA

For generation of different sized DNA fragment, two methods are generally used.

(i) **Sanger's method** in which dideoxyribonucleoside triphosphates are used to terminate DNA synthesis at different sites.

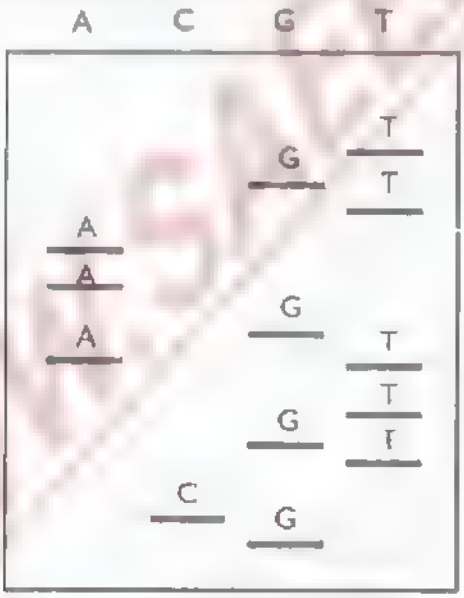
(ii) **Maxam-Gilbert method** in which DNA threads are chemically cut into pieces of different sizes.

Separation and Reading of Gene Sequence

DNA sequence is now completely automated, robotic devices mix the reagents and then load, run and read the order of nucleotide bases from the gel.

Sanger Method

- It is also called as enzymatic or dideoxy method.
- Chain terminating nucleotides labelled with different colored fluorescent dyes are used.
- All four synthesis reactions are performed in same tube and products are separated in a single lane of a gel.
- A detector (positioned near the bottom of the gel) reads and records the colour of fluorescent label on each band as it passes through a laser beam.
- A computer then reads and stores this nucleotide sequence.



Deduced Sequence	Fragment Size
G	19
C	20
T	21
G	22
T	23
T	24
A	25
G	26
A	27
A	28
T	29
G	30
T	31

Significance

Using this automation of DNA sequencing, genomes of many organisms have been sequenced e.g. plant chloroplast, animal mitochondria, bacteria, yeast, a nematode worm, Drosophila, model plant Arabidopsis, mouse and human. Researchers have also deducted the complete DNA sequence of a variety of human pathogens.

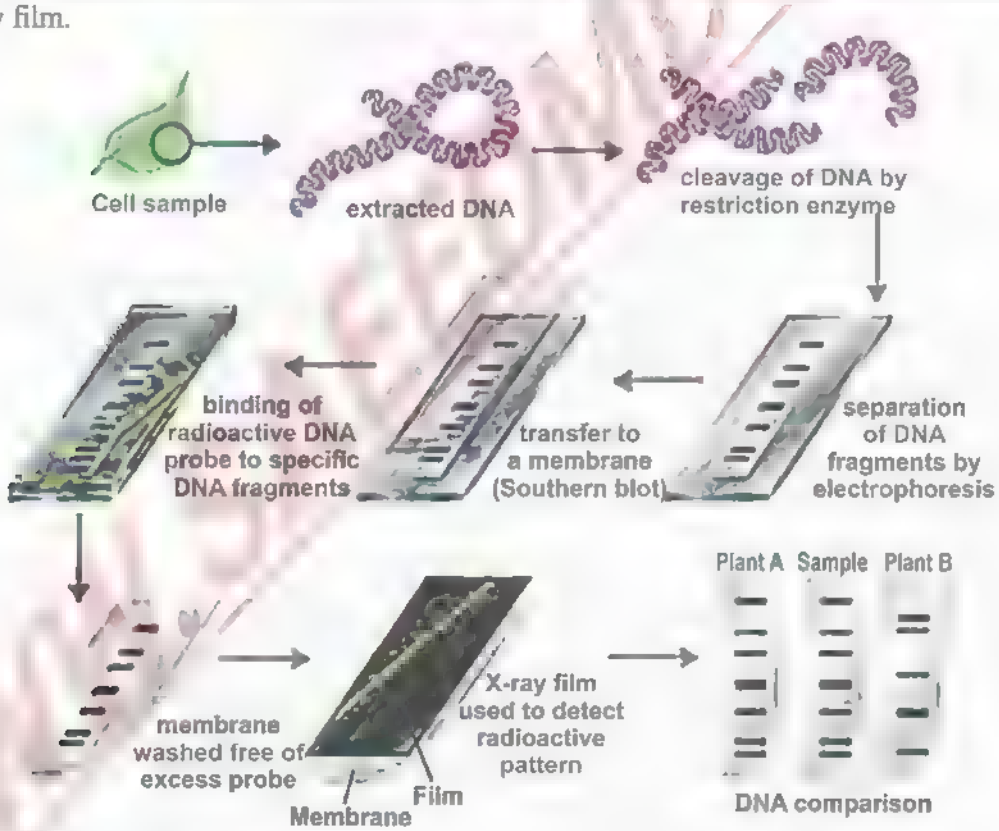
DNA ANALYSIS

It is a process by which entire genome of an individual can be analyzed.

Basic Mechanism

Different steps involved in DNA analysis are as follows:

- The genome is treated with restriction enzymes, which results in a unique collection of different sized fragments. These fragments vary in length and restriction enzyme separates according to this length, which is different in different individuals. This process of existing in different lengths is called restriction fragment length polymorphism (RFLPs).
- Fragments of genome can be separated according to their lengths through a process called gel electrophoresis.
- **Gel electrophoresis** is a technique used for the separation and analysis of macromolecules (DNA, RNA and proteins) and their fragments, based on their size and charge.
- It results in formation of a number of bands that are so close together that they appear as a smear.
- Use of probes for genetic markers produces a distinctive pattern that can be recorded on X-ray film.



Importance of DNA Analysis

- It can be used to solve disputes of paternity.
- It is important in forensic laboratories as evidence to solve crimes.
- PCR amplification and DNA analysis can be used to diagnose viral infections, genetic disorders and cancer.
- These can also be used to determine evolutionary history.

Organisms that have any foreign gene inserted in them are called **transgenic organisms**.

Transgenic Bacteria

Bacteria having foreign gene are called **transgenic bacteria.**

Methods of Production and Propagation

- Recombinant DNA technology is used to produce bacteria that reproduce in large vats called **bioreactors**.

Significance

- These are used to get various biotechnology products for human use.
- Biotechnology is used to convert **frost-plus to frost-minus bacteria**.
- These are used to produce **insect toxins** in plant cells.
- Bacteria can be used in industries as **bio-filters**.
- They are also used in biosynthesis of different chemicals e.g. phenylalanine, chemical needed to make aspartame (the dipeptide sweetener) better known as **Nutrasweet**.
- These bacteria are used in **bio-leaching**.
- Bacteria are also used in cleaning up beaches after **oil spills**.

Transgenic Plants

Plants having any foreign gene are called **transgenic plants.**

Methods of Production and Propagation

Insertion of Gene through Current

A foreign **gene** isolated from any type of organism is placed in the tissue culture medium. This tissue culture contains protoplasts. High voltage electric pulses are used to create pores in the plasma membrane so that DNA enters.

Insertion of Gene through Bacterium

A plasmid is used to produce recombinant DNA. This recombinant DNA contains foreign gene. It is inserted into plasmid of bacterium **Agrobacterium**, which normally infects the plant cells. When bacterium infects the plant, recombinant DNA is introduced into plant cells.

Insertion through Particle Gun

This method was developed by **John C. Sanford and Theodore M. Klein** of Cornell University in 1987.

Many plants including corn and wheat varieties have been genetically engineered by this method.

They constructed a device; particle gun that bombards a callus with DNA coated microscopic metal particles. Then genetically altered somatic embryos developed into adult plants.

Significance

- Transgenic forms of cotton, corn and potato have been made which are resistant to pests because they produce insect toxins. Soybeans have been made resistant to a common herbicide. Some corn and cotton plants are both pest and herbicide resistant
- A weed called mouse-eared cress has been engineered to produce a **biodegradable plastic (polyhydroxy butyrate)** in cell granules.
- Plants are being engineered to produce human **hormones, clotting factors** and **antibodies** in their seeds. One type of antibody made by corn can deliver radioisotopes to tumor cells. Antibody produced by soybean can be used as treatment for genital herpes. Plant made antibodies are inexpensive and have little chances of contamination.
- Improvements are going in improving quality of food.

Transgenic Animals

Animals containing foreign DNA in their cells are called transgenic animals.

Methods of Production & Propagation

- Transgenic animals have been developed by inserting genes into the eggs of animals
- In order to get transgenic animals, **two methods** are used i.e. **microinjection** (by hand) and **vortex mixing method,** by inserting gene into egg.
- In Vortex method the eggs are placed in an agitator with DNA and silicon-carbide needles. The needles make tiny holes through which the DNA can enter.

Significance

- **Gene pharming** is the use of transgenic farm animals to produce pharmaceuticals.
- Genetic engineering is done to improve quality and quantity of food obtained from animals.
- **Urine** is a **preferable vehicle** for a biotechnology product than milk because;

(i) All animals in herd urinate while only females produce milk.
(ii) Animals start to urinate at birth while female do not produce milk until maturity.
(iii) It is easier to extract proteins from urine than from milk.

POINT TO PONDER

Name three human organs

POINT TO PONDER

What is role of anti-thrombin

TISSUE CULTURE

- Tissue culture is the growth of a tissue in an artificial liquid culture medium, also called micro-propagation.
- German botanist **Gottlieb Haberlandt** in 1902 said that, plant cells are totipotent.
- Cornell botanist **F. C. Steward** in 1958 first time grew a complete carrot plant from a tiny piece of phloem.
- Tissue culture techniques are used to produce millions of identical seedlings in a limited amount of space. Common methods used in this are following.

Meristem Culture

- In this method, meristematic cells are used.
- Meristem is virus free portion of plant.

Procedure

- Different steps involved are:

(i) A small piece of tissue, usually mesophyll tissue from a leaf, is taken and enzymes are added to digest cell wall and convert it into protoplast.
(ii) Protoplasts regenerate a new cell wall and begin to divide due to presence of auxins and cytokinins in liquid medium.
(iii) Clumps of cells are manipulated to produce somatic embryos. These somatic embryos (sometimes called artificial seeds) are encapsulated in a protective hydrated gel. Somatic embryos of tomato, celery, asparagus, lilies, begonias and African violets can be produced in millions in large tanks called bioreactors.
(iv) A mature plant develops from each somatic embryo. Plants generated from somatic embryo vary somewhat because of mutations that arise during the production process. These are called **somaclonal variations.**

Anther Culture

- It is a technique in which mature anthers are cultured in a medium containing vitamins and growth regulators
- It is useful in plants that express **recessive alleles.**

Procedure

- Different steps involved are

(i) Haploid tube cells within pollen grain divide, producing pro embryos consisting of as many as 20-40 cells.

(ii) Pollen grains rupture releasing haploid embryos.

(iii) Haploid plant can be generated or chemical agents are added that encourage chromosomal doubling

(iv) After chromosomal doubling, resulting plants are diploid but homozygous for all their alleles.

Cell Suspension Culture

- This technique is used to get biotechnology products within culture medium
- It will no longer be necessary to farm plants for the purpose of acquiring the chemicals they produce.
- Cell suspension cultures of *Cinchona ledgeriana* produce quinine and *Digitalis lanata* produce digitoxin.

Procedure

- Different steps involved are:

(i) Rapidly growing cultures are cut into small pieces and shaken in a liquid nutrient medium so that single cell or small clumps of cells break off and form a suspension.

(ii) These cells produce the same chemicals as the entire plant.

BIOTECHNOLOGY AND ITS APPLICATIONS IN HUMAN HEALTH

Biotechnology has made a huge difference in human health care and has now enabled scientists to develop products which can give quicker and more accurate tests, therapies that have a lot less side effects and vaccines which are safer than ever before.

Role of Biotechnology in Treatment and Diagnosis of Diseases

Biotechnology is used in three different ways in the development of vaccine:

- Separation of a pure antigen using a specific monoclonal antibody
- Synthesis of an antigen with the help of a cloned gene.
- Synthesis of peptides to be used as vaccines.
- Many human diseases can be diagnosed by using products of biotechnology like monoclonal antibodies and DNA/RNA probes

Gene Therapy

- **Gene therapy** is the insertion of genetic material into human cells for the treatment of a disorder.
- There are two main methods for gene therapy i.e. **Ex-vivo and In-vivo.**
- Gene therapy for cancer patients makes cancer cells more vulnerable to chemotherapy and normal cells more resistant to chemotherapy.
- During coronary artery angioplasty, a balloon catheter is sometimes used to open up a closed artery.
- It will be possible to use in-vivo therapy to cure hemophilia, diabetes, Parkinson's disease or AIDS.

- To treat hemophilia, patients could get regular doses of cells that contain normal clotting factor genes or such cells could be placed in **organoids**, artificial organs that can be implanted in the abdominal cavity.
- To cure Parkinson's disease, dopamine-producing cells could be grafted directly into the brain.

Disease	Defect	Effect	Method		
SCID	ADA Deficiency	Immune deficiency, life threatening infections	Ex-vivo	Modified retrovirus	Bone marrow stem cells
Familial Hypercholesterolemia	Lack of receptor on liver cells for cholesterol	Fatal heart attacks	Ex-vivo	Modified retrovirus	Liver cells
Cystic Fibrosis	Trans-membrane carrier of Cl⁻	Numerous infections of respiratory tract, thick mucus plug	In-vivo	Liposome-microscopic vesicles (lipoproteins coated with gene)	Epithelial cell mucous cells, goblet cells
Heart Attack	Blockage of coronary artery	Necrosis of myocardium	In-vivo	Plasmid containing gene for vascular endothelial growth factor	Endothelial cells

TOPIC-19 MAN & HIS ENVIRONMENT / ECOSYSTEM

COURSE CONTENT

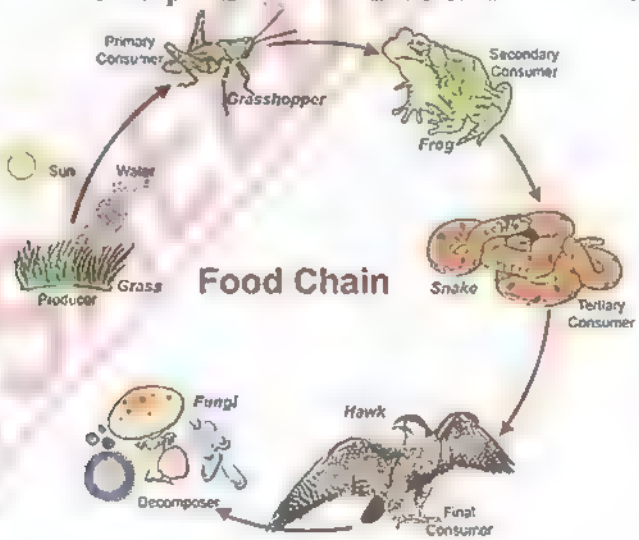
- Food chain, Food Web, Energy Flow
- Succession
- Symbiosis (Mutualism, Commensalism, Parasitism, Predation)
- Parasitism and Predation and Their Significance
- Biogeochemical cycles (N_2 Cycle)
- Human Impacts on Environment
- Acid Rain
- Greenhouse Effect
- Ozone Layer Depletion
- Algal Blooms

FOOD CHAIN, FOOD WEB, ENERGY FLOW

Food Chain

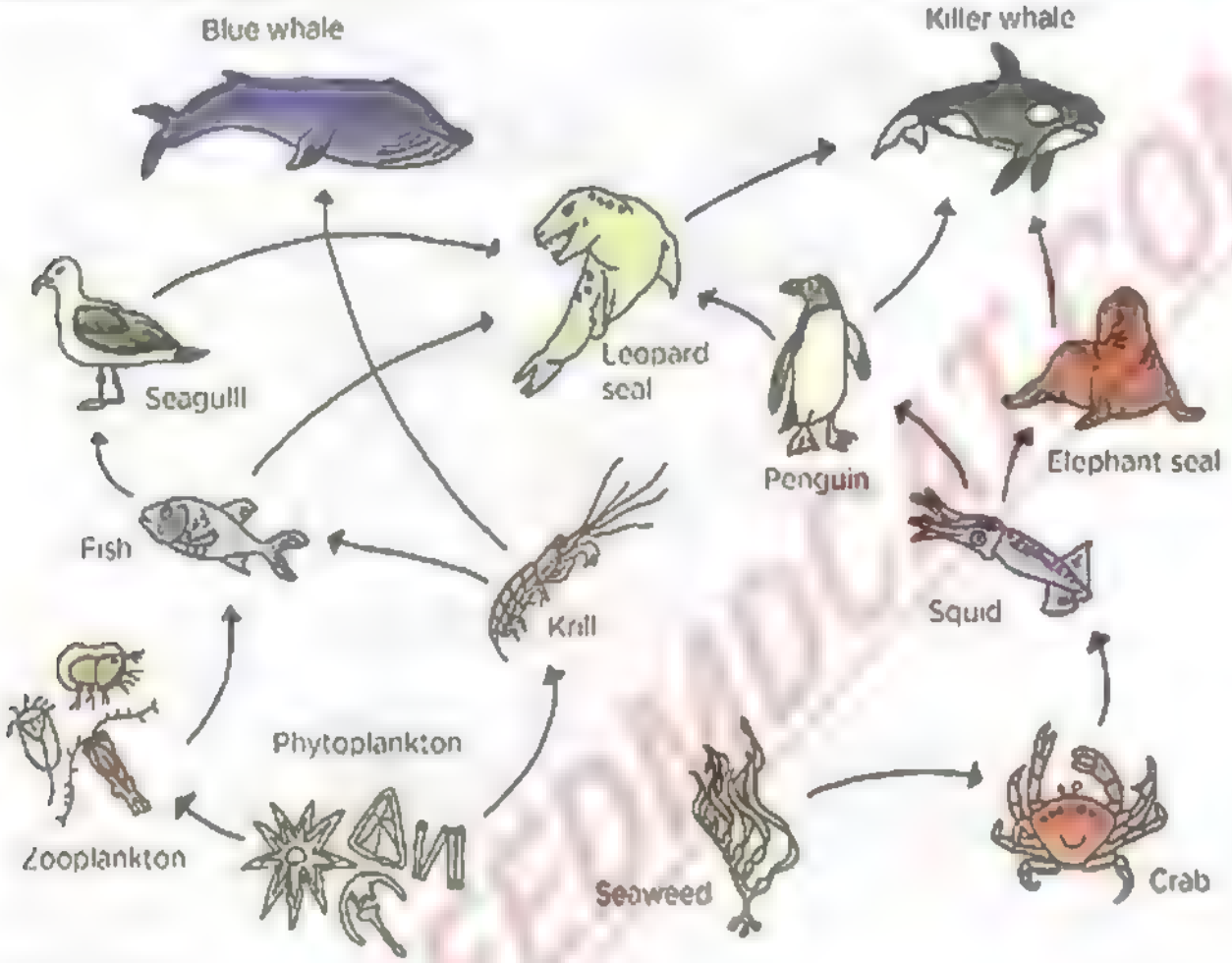
- Linear arrangement of organisms on base of feeding relationship is called food chain.
- All animals depend on plants for their food.
- All food chains start with producers (plants or algae).
- Simple food chain:

Grass → Caterpillar → Blue bird → Eagle



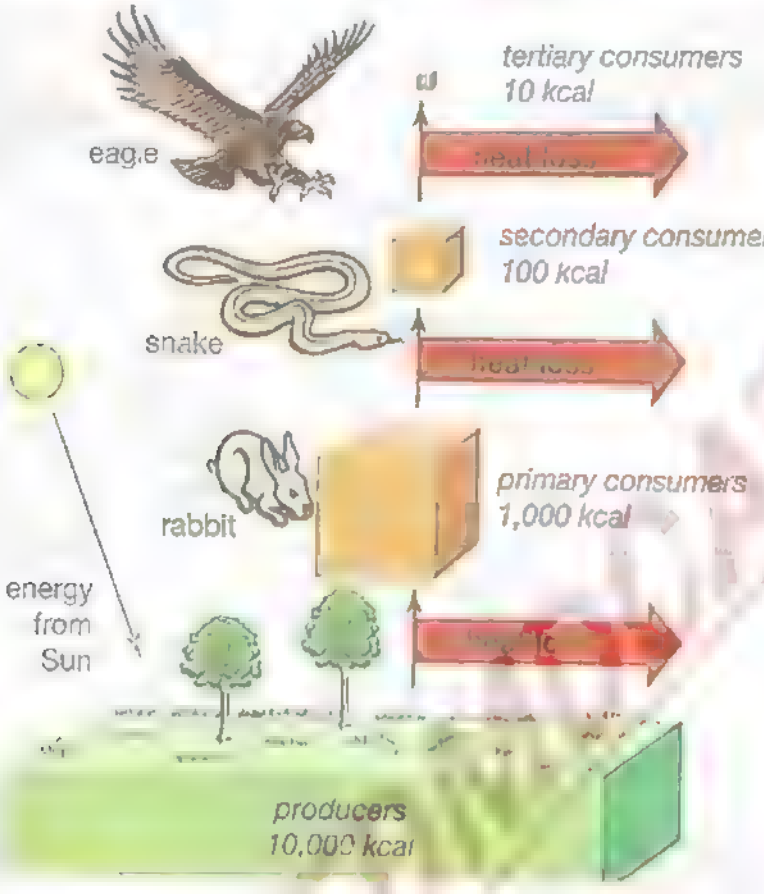
Food Web

- Combination of many food chains is called **food web.**
- Food webs consist of **3-5 trophic levels**
- Different trophic levels in food web are:
  - T_1: Producer
  - T_2: Primary Consumer/ Herbivores
  - T_3: Secondary Consumers/ Carnivores
  - T_4: Tertiary Consumers/ Carnivores
- The variety of pathways in a food web helps to maintain the stability of the ecosystem.



Energy Flow

- Energy in the form of radiant heat and light from the sun flows through an ecosystem passing through different trophic levels (links) and radiates again back into outer space.
- About 1% of the total energy from the sun is trapped by the producers in an ecosystem. The remaining 99% of solar energy is used to evaporate water, heat up soil and is then lost to outer space.
- The total amount of energy fixed by plants is **gross primary production**.
- The amount of energy left after plants have met their respiratory needs is net primary production, which shows up as plant biomass. (Gross primary production minus respiratory loss = **Net Primary Production/ Plant Biomass**.
- As energy is transferred from one trophic level to the next, from producer to primary consumer, 80-90% of the original energy is lost in form of heat as byproduct of respiration and only 10-20% is available to next trophic level.
- A short food chain of two or three links supports a community more efficiently than a long chain of five links where much of the original energy from the producers would never reach those organisms at higher trophic levels.
- Decomposers are able to obtain energy by converting plants and animal tissues and waste into inorganic material ions.



Productivity

- Productivity can be indicated by consumption of CO_2 and evolution of O_2 during photosynthesis.
- Primary productivity is amount of energy fixed by plants per unit area and unit time.
- Its unit is Kcal/M^2/YR.
- Productivity of aquatic ecosystem is basically determined by the **light and nutrients.**
- Light intensity and quality vary with the water depth, so the primary productivity also varies with light. The amount of nutrients also changes with season
- In temperate grassland, rate of primary production is about 700–1500 g m^2 annually
- In sub humid tropical grassland, it is more than 4000 g m^2 annualy

POINT TO PONDER

- **Succession** is a change in community and its non-living environment over a period of time.
  Succession is a sequence of events in community structure of ecosystem over period of time.
- It is also called as community relay.
- Succession begins by a few hardy invaders called **pioneers.**
- Diverse and stable community at the end of succession is called **climax community.**
- All the communities during succession are called as **seral communities.**

Types of Succession

- Succession on dry land takes two major forms, primary succession and secondary succession.

Feature	Primary Succession	ndary Succession
Definition	Such a succession where an ecosystem is forged from bare rock, sand or clear glacial pool where there is no trace of previous life.	A new ecosystem develops after an existing ecosystem is disturbed as in case of forced fire or an abandoned farm field.
Duration	As it is from scratch, so often requires thousands of years.	Due to previous community, it happens much more rapidly.

Primary Succession

- Primary succession starting in a pond is called **hydrosere.**
- Primary succession on a dry soil or habitat is called **xerosere.**
- Plants growing in xeric conditions are called **xerophytes**, which are able to withstand prolonged periods of water storage.
- Succulent plants like cacti have water stored in large parenchyma tissue

Stages of Xerosere

Crustose lichen stage	• Crustose means crust on the substratum. • Crustose lichen can live in extreme conditions • They absorb water during dry season • They are quiescent or dormant, normally desiccated during dry season.
Foliage lichen stage	• Lichens are just like crumpled leaves attached at one point • Produces shade to the crustose lichens as a result of which their growth is reduced or decreased. • Area becomes rough with more fissure and depressions develop • Examples are Dermatocarpon permellia
Moss stage	• Examples of mosses arepolytrichum, tortula etc. • They compete with lichens for water and penetrate deeper into the soil add more humus to the soil.
Herbaceous stage	• Small seedlings establish due to more availability of moisture, humus, soil for anchorage
Shrub stage	• Shrubby plants start growing and shadowing herbaceous plants which die and add more humus to the soil
Climax forests	• Woody plants develop due to improved soil • They dominate and this stage in succession remains essentially same if nothing changes in the environment to upset the balance

SYMBIOSIS
(MUTUALISM, COMMENSALISM, PARASITISM, PREDATION)

Mutualism

- It is association in which both organisms are benefited.

Examples

- Lichens are dual organism composed of symbiotic association of algae living within a fungus mycelium. The lichens grow on exposed rock surfaces and are important colonizers of bare ground.

- The legume plants (pea and bean) are hosts to symbiont bacteria, which inhabit the roots forming root nodules. The root nodules bacteria fix nitrogen in soil air, converting it into amino acids, which the host uses. In return host provides bacteria with food and protection.
- It is an association between the roots of plants growing in acid soil and certain fungi. The host is pine, beech or heather and it provides the fungus with an enzyme to digest carbohydrates in leaf litter.
  In return the fungus symbiont passes mineral ions from soil to the host.
- The insects get nectar from the flower. The flowers are able to reproduce because the insects carry pollen from flower to flower.

Commensalism

- In this type of relationship only one organism is benefited from the relationship. The other is not affected at all.

Example

- Sharks may have small fish called remoras attached to them. As the shark feeds, the remoras pick up the scrap The remoras benefits from this relationship while the shark is not affected at all.

Parasitism

This is an association between a host and a parasite, which involves providing the parasite with food, protection and conditions for its survival.

Significance

- Parasite may or may not harm the host.
- Mostly, they cause diseases in their host.
- Diseases in living organisms which are caused by parasite are called infestations.

Types and Examples

There are two types of parasites

(i) Ectoparasites; living outside the body of host e.g. fungi causing dandruff in hair.

(ii) Endoparasites; living inside the body of the host e.g. tapeworm in intestine of man.

Predation

- An animal that preys other animals is a predator A predator is a consumer.
- The animal that is caught is the prey.
- The overall process is called predation.

Significance and Relation

The sizes of populations of predator and prey are related to each other. The size of each population is determined by the size of the other.

- If number of prey is large, this leads to an increase in number of predators. As predator feeds upon the prey, the number of prey begins to fall.
- The number of predators decreases with decrease in prey as they have smaller food supply. As the number of predators decreases, the number of prey begins to increase. This food relationship of predator-prey creates a cycle.

Examples

Cat and mouse, fox and rabbit, seal and fish, frog and mosquito, hawk and small birds.

- **Biogeochemical cycle** or substance turnover is a pathway by which a chemical substance moves through biotic (biosphere) and abiotic (lithosphere, atmosphere, and hydrosphere) compartments of Earth.

Nitrogen Cycle

- The process by which nitrogen is circulated and re-circulated throughout the world of living organisms is known as **nitrogen cycle.**
- Nitrogen makes up 78% of the gases in atmosphere. Just as all organisms are ultimately dependent on photosynthesis for energy; they all depend on nitrogen fixation for their nitrogen.
- Organisms cannot use elemental atmospheric nitrogen to make amino acid and other nitrogen containing compounds, they are depending on nitrogen present in soil minerals.
- Nitrogen cycle mainly depends upon bacteria.

Stages of Nitrogen Cycle

- Principal stages of nitrogen cycle are;

(i) Nitrogen Fixation
(ii) Ammonification
(iii) Nitrification
(iv) Assimilation
(v) Denitrification

Nitrogen Fixation

- The process by which atmospheric nitrogen is converted into soil nitrates by microorganisms is called nitrogen fixation.
- Nitrogen fixing bacteria incorporate gaseous nitrogen from air into organic nitrogen-containing compounds.
- **Rhizobia** are involved in symbiotic nitrogen fixation while **Nostoc** is involved in non-symbiotic nitrogen fixation.

Ammonification

- Most of the nitrogen found in the soil is the result of the decomposition of organic materials and is in the form of complex organic compounds such as protein, amino acids, nucleic acid and nucleotides.
- These nitrogenous compounds are decomposed into simple compounds by soil-dwelling organism chiefly bacteria and fungi.
- Microorganisms in soil use the protein and amino acids and release excess of ammonia (NH_3) or ammonium ions (NH_4^+). This process is known as ammonification. Such bacteria are called ammonifying bacteria.

Nitrification

- Several bacteria in soil are able to oxidize ammonia or ammonium ions. This oxidation is known as nitrification.
- Important bacteria that are involved are *Nitrosomonas* and *Nitrobacter*.
- ***Nitrosomonas*** oxidize ammonia and ammonium ions into nitrites.
- ***Nitrobacter*** oxidize nitrites into nitrates.

Assimilation

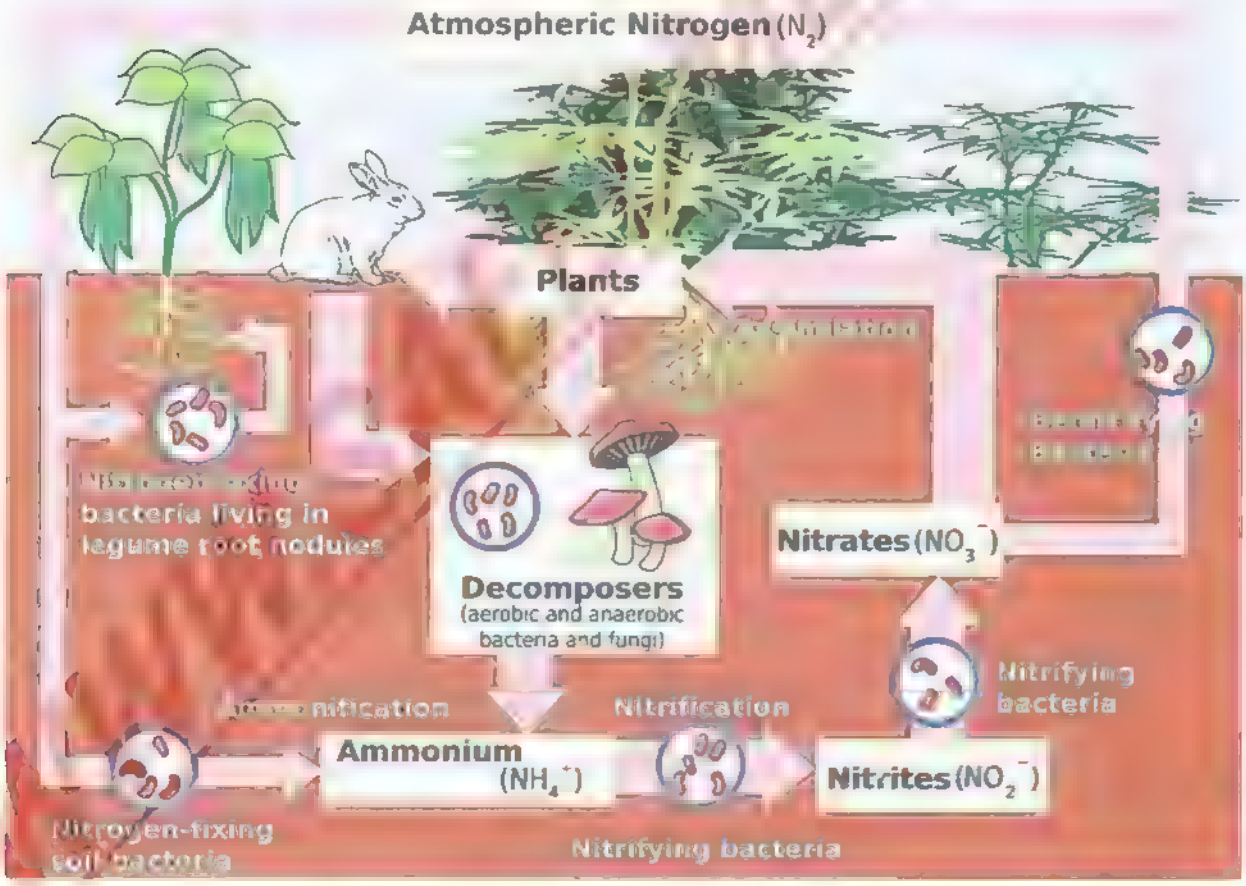
- Utilization of nitrogen inside the plant body cells for synthesis of nitrogen containing organic compounds is called assimilation.
- Nitrate is the form through which most nitrogen moves from the soil into the roots.
- Once nitrate is within the plant cell, it is reduced back to ammonium in contrast to nitrification. This assimilation process requires energy.
- The ammonium ions thus formed are transferred to carbon-containing compounds to produce amino acids and other nitrogenous organic compounds needed by the plants.

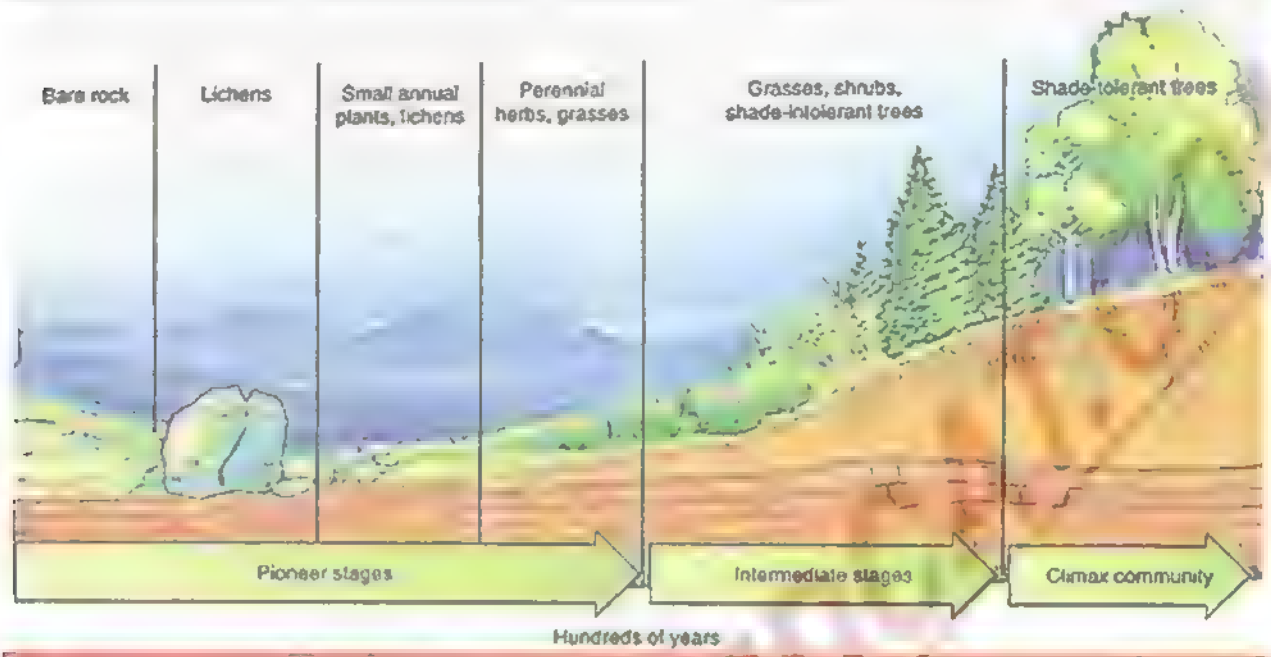
Denitrification

- Certain soil bacteria break down nitrates in absence of oxygen, releasing nitrogen back into the atmosphere and using oxygen for their own respiration. This process is known as denitrification.
- Soil nitrates are lost from **soil erosion**, **fire** and water percolating down through the soil.

Remedies of Nitrogen Depletion in Soil

Soil nitrogen resources are strengthened by the addition of nitrogen fertilizers by the man himself.





HUMAN IMPACTS ON ENVIRONMENT

Population

- **Demography** is the study of human populations and things that affect them.
- **Population of Pakistan** was 32.5 million in 1947. It has now increased to around 150-160 million in year 2000.
- About 20 years ago, human population was increasing at rate of 2% and was doubling every 35 years.

Deforestation

- Clearance of vast areas of forest for procuring lumber, planting subsistence crops or grazing cattle is called **deforestation.**
- The destruction of forests leaves the soil barren and it is called deforestation leading to **desertification.**
- **Reforestation** is replantation of plants in the areas where they were present earlier
- In reforestation coniferous species are important which often require bare soil to establish.
- **Afforestation** is establishment of new forests where no forests existed previously
- Forests are called as **environmental buffers** because they break speed of wind, rain and floods
- About half of the rain, which falls, in tropical forests comes from transpiration of these plants
- **Biodiversity** is total number of different species within an ecosystem and the resulting complexity of interactions among them.

Atmospheric Pollution

- The befouling of the air by anything that may be harmful to living organisms is air pollution.
- These harmful substances are called pollutants.

Air Pollutant	Source	Effects
Chlorofluorocarbons	• Aerosol spray foams • Air conditioning system • Refrigerants	• Thinning of ozone layer • Greenhouse effect • Global warming
Sulphur dioxide	• Power station • Fossil fuel	• Acid rains • Breathing disorders • Lung cancer
Lead compounds	Combustion of leaded petrol or oils	• Lead poisoning • Brain damage • Forest decline
Oxides of nitrogen	Burning of fossil fuels	• Global warming • Greenhouse effect • Acid rain • Headache& cough
Carbon monoxide	• Incomplete burning of carbonate & carbon compounds • Cigarette smoke	• Headache • Brain damage • Death

ACID RAIN

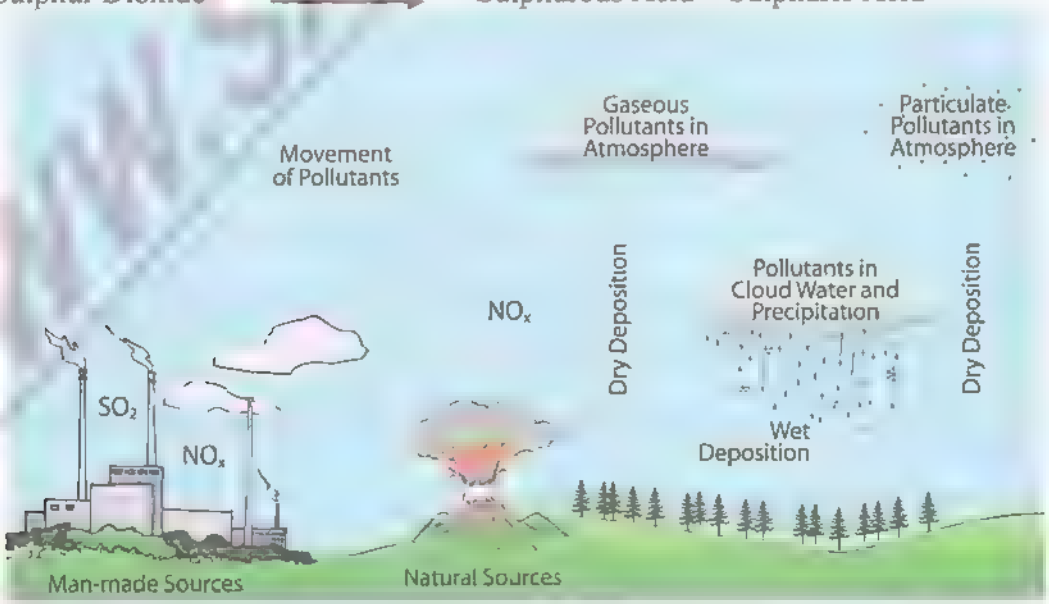
Process through which acids fall on earth either dissolved in rain or as microscopic dry particles is called acid rain.

Causes

- This is due to the overloading of nitrogen and sulphur cycle.
- Sulphur dioxide and nitrogen dioxide emitted in the air during the burning of fossil fuels combined with water vapours in the atmosphere and form acids.
- For example

Nitrogen Dioxide $\xrightarrow{\text{Water Vapours}}$ Nitric Acid + Nitrous Acid

Sulphur Dioxide $\xrightarrow{\text{Water Vapours}}$ Sulphurous Acid + Sulphuric Acid



Effects

Some of the important harmful effects of acid rains are

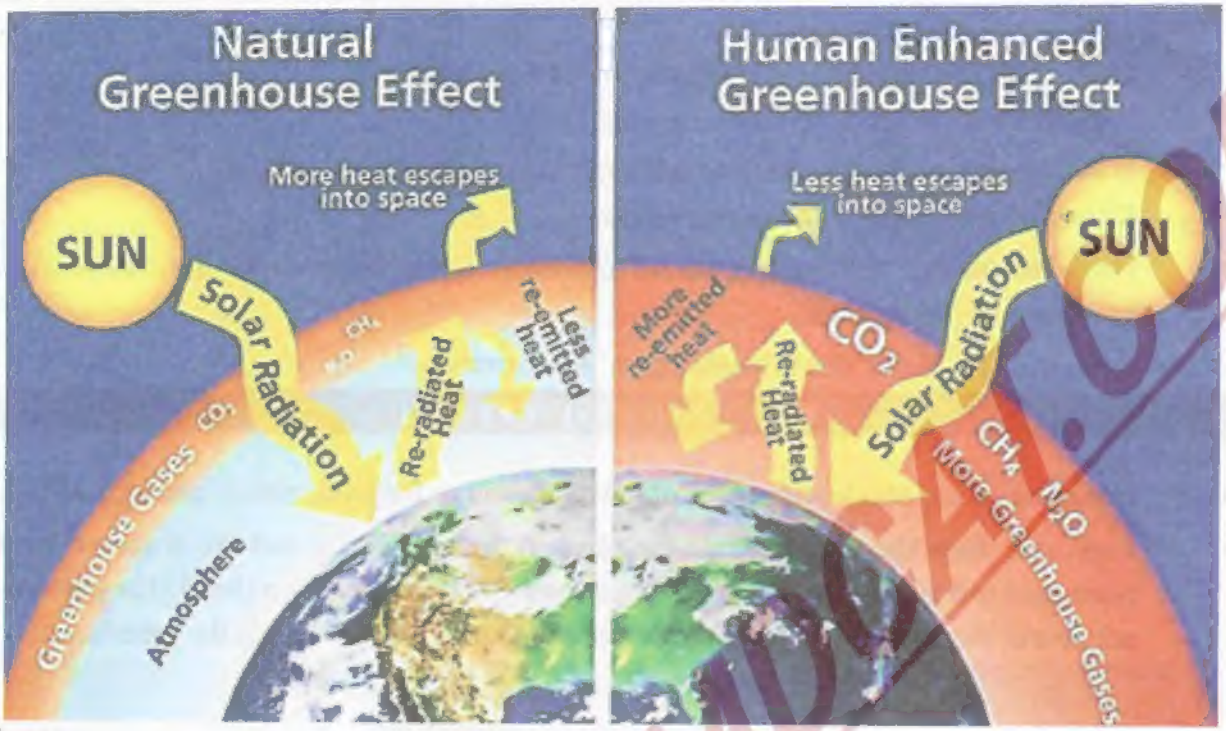
- Damage to life in lakes, farms and forests.
- Washing out essential nutrients of soil such as calcium and potassium.
- Killing of decomposers and microorganisms.
- Plants poisoning, and deprivation of nutrients makes them weak and vulnerable to infection and insect attack.
- Erosion of 'Taj Mahal' due to 'stone cancer' by acid rains.

GREENHOUSE EFFECT

Greenhouse

- Greenhouses are developed in area of low temperature for protection of plant growth.
- Light rays from the sun penetrate the glass of the greenhouse and are absorbed by the plants and soil and then reradiate as longer wave infra-red radiation (heat). The glass does not permit these rays to escape outside and so the heat remains within the greenhouse.

- The carbon dioxide of the atmosphere behaves like glass sheet of greenhouse. It absorbs the sun energy but does not allow it to escape outside, as a result of which temperature of the atmosphere increases.
- **Greenhouse gases** are those, which prevent heat to escape out from them e.g. CO_2.
- Increase in earth's atmosphere due to CO_2 and retention of heat rays is called **greenhouse effect or global warming**.



Causes

- Causes of greenhouse effect are:
- Over urbanization
- Deforestation
- Industrialization

Effects

This global warming may lead to:

- Rapid melting of ice caps and glaciers.
- Bringing floods and changing the path of major air and ocean currents.
- Drastic effects on global weather conditions.

OZONE LAYER DEPLETION

Ozone

- In pure form ozone is bluish, explosive and highly poisonous gas. Ozone molecule is made up of 3 oxygen atoms (O_3).

Ozone Layer

- Ozone is layer of atmosphere extending from **10-50 km** above earth.
- It filters and protects us from UV rays.

Ozone Depletion

- Decline in thickness of ozone layer is called **ozone depletion.**
- Ozone depletion is caused by increasing chlorofluorocarbons **(CFCs),** which contains chlorine, fluorine and carbon.
- These are produced from air conditioners and refrigerators.
- A single chlorine atom can react with ultraviolet rays and destroys as many as one million ozone molecules.

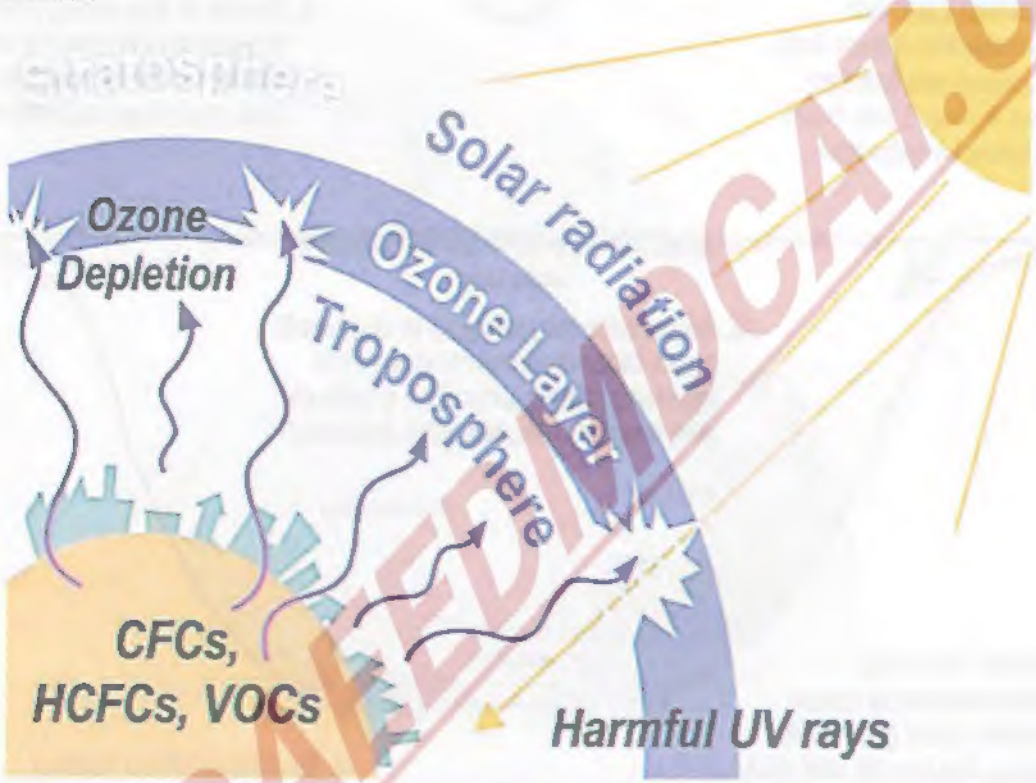
POINT TO PONDER

Why ozone layer depleted in Antarctica?

- The level of ozone in the ozone layer over the **Antarctica** has fallen drastically and has led to a hole.

Effects of Ozone Depletion

- More ultraviolet rays from the sun are able to reach earth.
- This entry of UV rays is affecting all life on earth by increasing temperature.
- They cause skin cancers and cataract in human.
- They can also affect crops, plants, trees and even marine plankton and distort weather patterns.



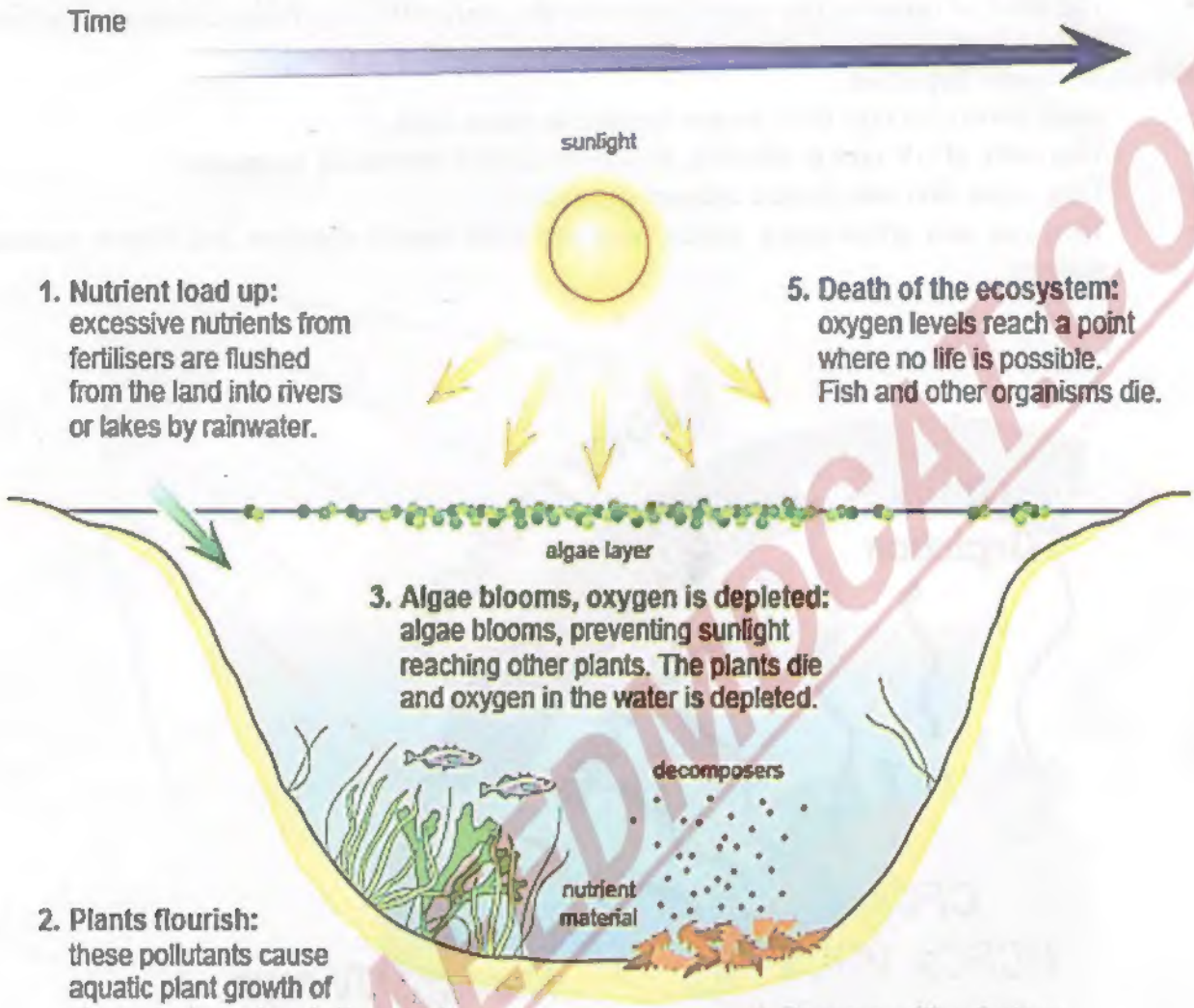
ALGAL BLOOMS

- It is natural process of excessive enrichment of water with nutrients by which large amount of living organic matter grows in the water.
- Human activities have speeded up this natural process of eutrophication by adding mineral and organic nutrients in larger quantities than nature would provide, as excreta, phosphates from washing powder and nitrates and phosphates from fertilizers.
- It occurs in fresh water and in sea water, both developing unpleasant color and smell.

Procedure

Different steps involved are;

- Different chemical wastes travel to water reservoirs.
- Vast quantities of algae feed and reproduce on these nutrients causing the water to turn green with algal bloom.
- The dead algae are decomposed by aerobic bacteria, which deplete the water oxygen content causing death of aquatic animals through oxygen lack.



POINT TO PONDER

What is algal bloom?